Using the Project 2061 Curriculum Analysis to Rate Two Middle School Science Curriculum Units: *ARIES: Exploring Motion and Forces* and *GEMS: The Real Reasons for Seasons.*

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**Background**
Major barriers to improving science education in the United States include the quality of science curriculum overall—an unfocused and splintered vision; the low quality of textbooks and curriculum materials used by teachers and students (U.S. National Research Center for TIMSS, 1996); and, the teachers’ difficulties with implementing reform-based curricula (Lynch, 1997; Lynch, 2000) and in delivering instruction consistent with educational reform goals (Lynch, 2000; National Commission of Science and Mathematics Teaching for the 21st Century, 2000; Wenglinsky, 2000). National systemic reform initiatives point to the need for a more focused science curriculum and better curriculum materials for teachers to use (aligned with science standards, instructional methods, and assessment/accountability measures). U.S. science textbooks are larger than those of other countries, but they are also less comprehensible, more repetitious, and tend to ask students to do tasks that only require low-level kinds of thinking (U.S. National Research Center for TIMSS, 1996).

It is reasonable to assume that improved curriculum materials aligned with science education standards that encourage students to learn with understanding could accelerate the reform process (given qualified teachers and reasonable resources). Consequently, the National Science Foundation, the National Research Council, the USDOE, and the American Association for the Advancement of Science’s (AAAS) Project 2061 all are involved in efforts to stimulate the creation of improved curriculum materials or to develop rating systems that identify promising, extant standards-based curricula. These rating systems rely on experts who examine curriculum materials for critical, research-based attributes believed to contribute to successful teaching and learning (Kesidou & Roseman, 2002).

Project 2061 has launched a major effort to find curriculum materials aligned with benchmarks that meet a rigorous set of criteria consistent with current theories of learning and content specific instructional strategies that support learning (Kesidou and Roseman, 2002). The Project 2061 Curriculum Analysis consists of categories of questions for analyzing the instructional qualities of a unit. However, the Project 2061 Curriculum Analysis is not without criticism. The Curriculum Analysis does not include the universe of all desirable characteristics of curriculum materials, but rather a number of attributes with rationales supported by research literature (see Kesidou & Roseman, 2002, Holliday, 2003, and Kesidou & Roseman, 2003 for a more extensive discussion). Holliday (2003) raises concerns about potential for bias in the training of the rating teams and the quality of the 22 instructional criteria. In addition, the Curriculum Analysis is a process conducted by a group of experts (based upon education research and best practice), but has not been evaluated or field tested in schools. Thus, it seems reasonable to proceed cautiously regarding claims for its efficacy, at this point (Lynch, Kuipers, Pyke, Szesze, 2003).

**Context for this study**

The need to do curriculum analyses for two middle school science curriculum units was precipitated by a NSF/IERI research grant entitled, Scaling Up Highly Rated Science Curricula in Diverse Student Populations: Using Evidence to Close Achievement Gaps (Lynch, Kuipers, Pyke, & Szesze, 2002). A goal of this research was to locate “reform” or “standards-based” middle school science curriculum units, and scale them up in a large, diverse, public school system, over six years. It was understood that the units would likely have in common a well-defined set of instructional attributes that would lead to improved outcomes when compared to “standard” curriculum materials already in
use in the school system. However, this study also seeks to learn if the scaled-up units might result in better outcomes for various subpopulations of students (defined by gender, socioeconomic status, ethnicity, and status as a learner of English or as having an identified disability). In the preliminary phases of our study, we implemented an eighth grade curriculum unit, *Chemistry That Applies* (CTA) (State of Michigan, 1993). CTA had received a high rating according to the Curriculum Analysis conducted by Project 2061 (AAAS, 2001b), and was one of the few existing middle school science curriculum units to have done so. In our study, students in five highly diverse middle schools had statistically significant higher outcome scores than their counterparts in five comparison schools who studied the same concepts with the standard curriculum materials (Lynch, Kuipers, Pyke, Szesze, 2003).

Because of the success of CTA, it seemed likely that if we were able to locate materials with similar characteristics for the 6th and 7th grade components of our study, then we might expect similar positive results and be in the position to ascertain which qualities of the curriculum materials seem likely to contribute to increased student outcomes, especially for a diverse student population.

So, as Scaling up Curriculum for Achievement, Learning, and Equity Project (SCALE-uP) research proceeded, we sought to identify two additional curriculum units that also would earn a high rating on the Project 2061 criteria, (one for sixth grade science and one for seventh). These new units had to align with the local school district’s curriculum framework, be cost and time efficient, and have the potential for rating highly on the Project 2061 Curriculum Analysis. We examined a number of “reform-oriented” middle school science curriculum units. Many of these had their provenance with NSF’s curriculum development efforts. After much searching, the research/science education staffs at the local district and university were able to find only two curriculum units that seemed suitable: ARIES: *Exploring Motion and Forces* (Harvard-Smithsonian Center for Astrophysics, 2001) and Great Explorations in Math and Science: *The Real Reasons for Seasons* (Lawrence Hall of Science, GEMS, 2000). It was our hope that both units would receive high ratings on the Project 2061 Curriculum Analysis. This paper reports on the analyses for these two middle school science curriculum units.

**The Curriculum Units**

*Exploring Motion and Forces: Speed, Acceleration, and Friction* was developed for the ARIES curriculum program by the Science Education Department at the Harvard-Smithsonian Center for Astrophysics. *Exploring Motion and Forces* is a six-week physical science curriculum unit designed for grades 5-8. It has 18 “Explorations” divided into four units. All of the Explorations are inquiry-centered and activity-based, with an emphasis on students’ direct experience with phenomena. The curriculum materials themselves consist of a Teacher Manual and a student Science Journal. There is no traditional student text. Educators may buy all of the necessary materials in a prepared kit, or they may make up their own sets of student lab materials for each Exploration.

*The Real Reasons for Seasons*, by the University of California at Berkeley, Lawrence Hall of Science, is an astronomy/earth science based curriculum unit designed for grades 6-8 and divided into eight activities dealing with Sun-Earth connections. The unit gives students opportunities to reflect on their own ideas about what causes seasons, challenge those ideas, and revise their scientific understanding of the ‘real reasons for seasons’. The materials include a Teacher Guide, which has a CD-ROM for class
demonstration(s) and a Student Lab Book. Other materials for the eight activities may be purchased in a prepared kit but supplies are easily assembled from classroom materials.

Overview of the Project 2061 Curriculum Analysis

In the mid-90’s, Project 2061 convened three successive groups each consisting of science teachers, curriculum developers, and science teaching/learning experts (Kesidou & Roseman, 2002). These groups developed, discussed, and refined a set of research-based criteria to judge the efficacy of curriculum materials in teaching specific learning goals. Their work aimed to bridge the gap between recent research on learning (i.e., organization of expert knowledge, the role of prior knowledge in learning, the conditions that facilitate transfer of learning) and the evaluation of curriculum materials. These criteria attempt to take into account both the individual and social aspects of the learning process by asserting that students should be given opportunities to talk and/or write about, share, clarify, and distribute their knowledge. Curriculum materials that support teaching and learning in this way, should enhance the learning process for students (Kesidou & Roseman 2002).

The Project 2061 Curriculum Analysis consists of two distinct phases; the Content Analysis and the Instructional Analysis.

The Content Analysis follows the procedures used by Project 2061 in the Middle Grades Science Textbooks evaluation (AAAS, 1999). The Content Analysis requires reviewers to look closely at a curriculum material/unit to determine whether its content aligns with specific learning goals. The content should address the substance of the goal (such as a benchmark, standard, or local school district’s indicators) rather than be a superficial topic match (Kesidou & Roseman, 2002). The Content Analysis focuses on a set of ideas that comprise either an entire Project 2061 benchmark, (see Benchmarks for Science Literacy, 1993), selected parts of related benchmarks, or statements from the supporting text in Benchmarks for Science Literacy (1993). These benchmarks or standards can be considered as either a single “target idea” or an “idea set,” composed of related science concepts that students need to understand to learn the target idea/idea set.

If there is a good content match, then the Curriculum Analysis can enter the second phase, called the Instructional Analysis, which determines how well the material’s instructional strategies support student learning of the selected learning goal. The Instructional Analysis is divided into 22 separate criteria across seven sections or categories. The Project 2061 Instructional Analysis Criteria, indicators, and the rating scheme for each criterion (poor, satisfactory, or excellent) can be found in Appendix A.

Finally, both the Content and Instructional Analyses are finalized in a report, which includes the development of a criterion-by-criterion profile that shows how the learning goal is met by the unit’s instructional attributes (Kesidou & Roseman, 2002).

Methods

The Curriculum Analysis for both the Seasons and Motion and Forces units was completed during the spring of 2003 by teams brought together by SCALE-uP for this purpose. The Analysis process was led by Dr. Curtis Pyke and facilitated by Dr. Sharon Lynch, professors of secondary education at George Washington University. Project 2061 was not directly involved with this analysis. The SCALE-uP staff attempted to follow the Project 2061 Curriculum Analysis procedures as closely as possible. However, the Seasons and Motion and Forces analyses should not be construed as sponsored by Project 2061.
As the first step, the GWU SCALE-up research staff completed most of the groundwork for the Content Analysis (the identification of the learning goals and location of various “sightings” of evidence within the curriculum unit for those learning goals). Then an outside evaluation team of science/science education specialists traveled to the GWU campus to complete the Instructional Analysis for Seasons and Motion and Forces, using the Project 2061 procedures (see Appendix B for a list of team members).

The evaluation teams worked on the Instructional Analyses for about eight hours/day, for four consecutive days. The first day was mostly devoted to familiarizing the reviewers with the goals of the research grant and teaching them the Curriculum Analysis process. Each team had an opportunity to familiarize itself with its respective curriculum unit and participate in many of the student activities required by the curriculum unit. The teams also reviewed maps of the middle school benchmarks (learning goals) for forces and motion and astronomy.

In the next two days, each four-person evaluation teams broke into two pairs of partners who worked methodically through the Project 2061 Instructional Analysis Categories, pausing at intervals to discuss and reconcile their results. The teams used the final day primarily for writing the results of the Instructional Analyses. Finally, the GWU research team proofread and edited the evaluation teams’ work, and added supplementary information to create two final reports.

Results of the Content and Instructional Analyses

Content Analysis

The goal of Content Analysis (of the Project 2061 Curriculum Analysis) is to identify a target benchmark or standard (or a discrete set of targeted benchmarks/standards) aligned with the curriculum unit. The Content Analysis has three steps: 1) benchmark/standard selection; 2) the sighting phase (determining the locations or “sightings” of activities in the curriculum material that address specific benchmarks/standards); and, 3) determining quality of alignment (consisting of five components: alignment, building a case, coherence, beyond literacy, and accuracy) (AAAS, 1999).

The complete Content Analyses are provided in more detail in each of the Curriculum Analysis Technical Reports for the two units (Ochsendorf, Chen-Deprey, Lopez, Roudebush, Lynch & Pyke, 2003; Faubert, Geer, Skelton, Slater, Lynch & Pyke, 2003). Here, we present a summary of the ideas contained in the Content Analysis for both Seasons and Motion and Forces.

Benchmark/Standard Selection

The development of Target Concept Maps (Figures 1 and 2) was essential to determine the alignment of the content of Seasons and Motion and Forces to their respective target ideas. The maps were constructed using the convention established in Atlas of Science Literacy (AAAS, 2001a); a collection of strand maps that correlate to particular Benchmark ideas. Project 2061 has defined a strand map as “…identifiable concepts or stories that are developed in groups of benchmarks across different grade levels” (AAAS,
2001a, p. 6). Such a map is intended to show how students’ understanding of the ideas and skills that lead to literacy in science develop over time and help to display the explicit connections that exist among the individual benchmarks. With the help of these maps, the research team created an idea set resulting from the consideration of all possible benchmarks addressed in the ARIES and GEMS units, respectively.

For **Motion and Forces**, the result was a map (Figure 1) of target ideas that seemed to be the learning goal for this unit, and derived in part from a concept strand map found in *Atlas of Science Literacy* (AAAS, 2001, p. 63). The Content Analysis for **Motion and Forces** was aligned with a complete benchmark (AAAS, 1993, p. 89; 4F, 3-5, #1) and a section of text taken from *Benchmarks for Science Literacy* (AAAS, 1993, p. 90) that addresses Newton’s First Law of Motion. The aligned target ideas were:

- Changes in speed or direction are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.
- An object at rest stays that way unless acted on by a force. An object in motion will continue to move unabated unless acted on by a force (AAAS, 1993).

The **Reasons for Seasons** map (Figure 2), in contrast, had to be constructed “from scratch” because no age-appropriate extant map of these ideas could be found. This unit was well aligned with a single middle school benchmark (AAAS, 1993, p. 69; 4B, 6-8, #4) that addresses the idea of seasons along with other related ideas that the unit seemed to teach (from Figure 2, target ideas 1 through 3; spherical Earth, Earth’s rotation, and Earth’s orbit). The aligned target ideas were:

- Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns.
- The Earth is approximately spherical in shape.
- The rotation of the earth on its axis every 24 hours produces the night-and-day cycle.
- Planets….move around the sun in nearly circular orbits (AAAS, 1993).

Next, the research team found specific sightings for the respective benchmarks in the curriculum materials for both **Motion and Forces** and **Seasons**.

**Sighting**

After constructing a map and determining target idea alignment, the next step in the Content Analysis was to locate areas within the curriculum material that correspond reasonably well to the idea set displayed in Figures 1 and 2. This was accomplished by a meticulous, page-by-page survey of each units’ activities, investigations, reading selections, and other learning opportunities that address the target ideas within the idea set. This process is referred to as “sighting,” and included the specification of page number and quotes from the units that link to the target ideas. Two SCALE-uP research
assistants eventually arrived at a complete set of sightings for both Seasons and Motion and Forces.

Quality of Alignment

Quality of alignment explores and describes (a) how the curriculum materials align to each target idea, (b) the evidence provided by the material that builds a case for the ideas, (c) the connections the material makes among ideas in the idea set and to other ideas, (c) level of sophistication (that is, to determine if the coverage is appropriately aligned with the literacy expectations of the target grade level), and (e) the accuracy of the materials related to the ideas.

Seasons aligned well with each target idea, used evidence to build a case for the ideas, made appropriate connections among all of the target ideas and other ideas, maintained an age-appropriate coverage of the target ideas, and demonstrated solid scientific accuracy related to the ideas. Motion and Forces satisfied the same quality of alignment criteria, with a few notable exceptions. The unit does not seem to use evidence from the Explorations to build a case for the target ideas. Students are provided with numerous opportunities to observe phenomena that are specifically related to the target ideas but the material does not explicitly link these observations to students’ own conclusions about the target ideas or about the laws of motion. Also, it appears that Motion and Forces does not make explicit connections among the target ideas, but there are some connections made between the target ideas and the related and prerequisite ideas. While individual Explorations are based on phenomena related to the target ideas, it is often left to the student to determine how those ideas are related and which ideas learned from past Explorations are necessary for the next Exploration(s).

Instructional Analysis

The complete ratings and justifications from the Instructional Analysis are provided in more detail in each of the Curriculum Analysis Technical Reports for the two units (Ochsendorf, et al., 2003; Faubert, et al., 2003). Here, we present some of the highlights from each of the Instructional Analyses. The discussion will be organized for the Instructional Categories and provide evidence to support the ratings for the units. Because we are most interested in the instructional qualities of these units that may have the most significant impact on student learning, we will restrict our summary in this section to a discussion of the relative strengths of the two units. Therefore, at the beginning of each category, the corresponding satisfactory and excellent ratings will be shown for each curriculum unit.

When reading this section, it will be helpful to refer to the Curriculum Analysis criteria, indicators, and rating schemes found in Appendix A. Also, the complete results from the Instructional Analyses for the two units are summarized in Table 1 along with the ratings for the 8th grade unit, CTA (which was rated by Project 2061).

Category I. Identifying a Sense of Purpose. This category consists of three criteria: a) conveying unit purpose, b) conveying lesson purpose (M&F-Satisfactory, Seasons-Excellent) and c) justifying lesson sequence (M&F-Satisfactory, Seasons-Excellent).
For **Motion and Forces**, the reviewers found that although the first two Explorations address the two main concepts that are central to the unit (motion and force), the connection between these Explorations and a large vision of the study of the interaction between force and motion is not explicitly made for the students (Criterion A). It is unclear that students would be sure about what they are doing and why they are doing it, throughout the unit. **Motion and Forces** does do a satisfactory job of conveying a sense of purpose for each lesson (Criterion B). But, the criterion for the interconnection of each lesson or set of lessons (referred to as a “unit” by the materials) to the key ideas cannot be met because the students were never informed of the overall purpose of the unit, resulting in a ‘satisfactory’ rating on Criterion B. For Criterion C, there is a logical sequence within the unit (activities involve basic observation and descriptions of motion, a progression to how to start and stop motion, then investigating the role of friction and making observations about motion in the absence of friction, motion on an inclined plane, exploring how forces affect motion, and finally, the effect of mass on the amount of change in speed for a given force). Despite this logical sequence, a rationale is not conveyed to either the teacher or the students, resulting in the ‘satisfactory’ rating.

**Seasons** does a somewhat more effective job overall with identifying a sense of purpose. However, the reviewers felt that the unit did not make the overall unit purpose explicit enough to students at the beginning. They write, “there is nothing at the beginning of the **Seasons** unit directed toward the students that indicates which variables are important, such as the orientation of the Earth’s axis relative to the plane of its orbit around the Sun, as being critical to understanding the reasons for seasons” (Faubert, et al., 2003). The evaluation team interpreted the **Seasons** materials to instruct the teacher to withhold the unit purpose from the students. **Seasons** however, received excellent ratings for conveying lesson/activity purpose and justifying the sequence of the activities. Throughout the **Seasons** Teacher Guide, the teacher is prompted to remind students of the purpose of each activity, a considerably important criterion.

**Category II. Taking Account of Student Ideas.** This category consists of four criteria: a) attending to prerequisite knowledge and skills, b) alerting teacher to commonly held ideas (**Seasons-Satisfactory**), c) assisting teacher in identifying own students’ ideas (**M&F-Satisfactory**), and d) addressing commonly held ideas (**Seasons-Satisfactory**).

The reviewers found that, overall, **Motion and Forces** could be more effective at taking into account student ideas despite systematically asking students to reflect on prior knowledge, ask questions (Recording Ideas and Discussion Sections), or provide an opportunity to give explanations of their observations (Interpreting Results and Discussion Sections). The questions in these sections are related to students’ life experiences and often ask the students about the evidence needed to support a point of view. This judgment led to the satisfactory rating for Criterion C.

In addition, the structure of the unit asks students to examine their predictions by making direct observations or measurements. These predictions and related discussions can help students progress toward understanding these common notions, such as questions that ask students to consider their own experience while sliding down a slide, which, in turn, leads into the next Exploration’s activity of rolling a ball down a ramp.

The **Seasons** materials contain frequent references to common student difficulties and beliefs that are part of the anecdotal knowledge base of experienced astronomy/earth
science teachers. Also, Seasons explicitly describes some of the commonly held ideas that are documented in the research literature such as, the shape of orbits, and Sun-Earth distance as it relates to seasons. In addition, using the “Sun-Earth Survey”, students are frequently prompted to revisit their answers to the survey with questions like, “What can you change about your survey responses in light of what you just learned?”

Category III. Engaging Students with Relevant Phenomena. This category consists of two criteria: a) providing a variety of phenomena (M&F-Excellent), and b) providing vivid experiences (M&F-Excellent, Seasons-Satisfactory).

Motion and Forces overall provides an excellent variety of phenomena that are relevant to the key ideas being conveyed by the materials of instruction (Criterion A). These serve to make the key ideas real and accessible through direct experience. Instruction centers on hands-on experiences with equipment constructed from everyday materials. Connections with life experience are made in the introductory questions of each Exploration (for example, hockey pucks, child going down slide, and four wheeled vehicles). In addition, the unit is filled with nuggets of information relating the key ideas of this unit with life experiences. Phenomena include personal life experiences, and cultural and news items. In addition, the materials do an excellent job of providing a set of vivid, firsthand experiences for the students (Criterion B).

The reviewers felt that although both indicators were met for Criterion A and Seasons does an effective job of linking the phenomena to the key ideas, there were not a sufficient number of phenomena to warrant an excellent rating. For Criterion B, the phenomena and experiences for students in Seasons, (such as the “Mt. Nose” activity, graphing temperatures around the world, and day length graphing), although not first hand, do provide students with a vicarious sense of the phenomena, which they are intended to address. This justified the satisfactory rating for this criterion.

Category IV. Developing and Using Scientific Ideas. This category consists of four criteria: a) Introducing terms meaningfully (M&F-Satisfactory, Seasons-Satisfactory), b) representing ideas effectively (M&F-Satisfactory, Seasons-Excellent), c) demonstrating use of knowledge (Seasons-Satisfactory), and d) providing practice.

Both Motion and Forces and Seasons do an effective job introducing terms meaningfully. In Motion and Forces for example, technical terms were introduced using relevant material. For example, the key ideas of motion, force and friction are all defined through experience. Seasons, as well, does an effective job of introducing key terms through meaningful experiences such as ellipse, altitude, foci, diameter, longitude, and latitude.

Similarly, both units do an effective job of representing the target ideas. Specifically, the reviewers felt that Motion and Forces contained many effective analogies and metaphors for the key ideas. Some examples from the unit include sliding down a slide, curling, fan boats in the Everglades, a soapbox derby, earth’s motion around the sun, and Mercury and Pluto orbiting the sun. The content of these representations is, for the most part, accurate and in most cases, the students will be able to relate the representation to the content of the lesson. Seasons also includes representations that are accurate, likely to be comprehensible to students, and explicitly
linked to the real thing (Activity 7-Tilted Earth is a clear example). In particular, the CD-ROM provides numerous examples to help students link ideas to real world experiences.

Category V. Promoting Student Thinking about Phenomena, Experiences, and Knowledge. This category consists of three criteria: a) encouraging students to explain their ideas (M&F-Satisfactory), b) guiding student interpretation and reasoning (Seasons-Satisfactory), and c) encouraging students to think about what they’ve learned.

Throughout all of Motion and Forces, the unit routinely encourages students to express their ideas. Students are asked to answer questions or prompts in “Recording Your Ideas” (e.g., “So why do you think so?”) “Exploration Procedures” (e.g., “What do you predict would happen if you placed a marble halfway up the inclined track?”) and “Interpreting the Results” (e.g., “Why do you think the Air Disk eventually stopped moving?”). The students are routinely asked to clarify, justify and, represent their ideas in every Exploration. Students are given opportunities not only to answer questions but to ask questions as well.

In Seasons, the activities provided in the book promote an environment where students are carefully guided through specific sequences of questions that lead them to make relevant observations and draw the scientifically accurate relationships and inferences from those questions.

Conclusions

In general, Motion and Forces and Seasons share some similar instructional qualities and apparent strengths. For example, both units provide students with a variety of vivid experiences that are related to the key ideas (Project 2061 Instructional Category III). Motion and Forces includes a series of 18 Explorations organized around activities and phenomena related to a sliding air disk, an inclined track, a rolling cart, and a fan cart. Similarly, Seasons provides activities involving models and representations of the phenomena (i.e., CD-ROM activities). As our SCALE-uP research continues, we look forward to exploring the importance of this particular category in enhancing student learning. In addition, both units effectively create a sense of lesson purpose for the students as they work through activities. Both units also do a reasonable job in developing and using scientific ideas. Some of these criteria may prove to be more critical than others in helping students learn the target ideas.

For the purposes of our scale-up research, we have used the Project 2061 Curriculum Analysis to systematically examine and rate the instructional qualities of the units to be implemented in a five-year study. This process provides a comprehensive, research-based tool for determining the quality of instructional materials. The Curriculum Analysis seems to be a reasonable and thoughtful first step in specifying the characteristics of curriculum materials likely to improve outcomes for a diverse middle school student population. In addition, the analyses allow a comprehensive initial comparison for the three curriculum units that will be used in our study, acknowledging that they have different instructional approaches for three different content areas.

We view these analyses of Motion and Forces and Seasons as an ongoing process for better understanding important features of curriculum materials. The Project 2061 Curriculum Analysis procedure has provided us with one ‘window’ for examining the
quality and content of curriculum materials using a well-developed rating scheme that relies on teams of trained reviewers who spend considerable time examining the written and accessory resources provided by publishers. To continue this work, we have established a productive dialogue with the two curriculum development groups that created these units. We have invited the curriculum developers from GEMS and ARIES to respond to the Curriculum Analysis processes and criteria, as well as to the judgments and rationales of the review teams. We know that curriculum developers have their own set of criteria for constructing their materials, and we are eager to understand how these criteria compare with those in the Project 2061 Curriculum Analysis. Adding to this complex picture of curriculum development and potential efficacy, we know that the developers have conducted a series of field-tests of their units which inform their views. They have seen the materials used in classrooms and have used teacher feedback for revisions, framing their judgments in experiential terms.

As SCALE-uP implements these two units in five middle schools reaching about 1500 students and 15 science teachers in the 2003-2004 school year, we are eager to see how the materials are received in real school settings using a quasi-experimental study design and a sample of 3000 students, as well as a video ethnography. This can provide another perspective on the strengths of these units, exploring questions such as:

- Are there specific instructional qualities about these units not captured in the Curriculum Analysis revealed through the analysis of classroom video data?
- Can we use student outcome to provide evidence about the efficacy of these units for a diverse student population?
- Can classroom observations contribute to understanding the extent to which instructional components of the units are being enacted as intended by the units?

As we attempt to answer such questions, we look forward to continued dialogues with both Project 2061 and the curriculum developers that may help to inform curriculum rating procedures and clarify the qualities of these materials that enhance student learning. In doing this, we hope to contribute to understanding how improving science curriculum materials can result in improved outcomes for all U.S. students.
References


Appendix A.

AAAS Project 2061 Instructional Analysis.

Category I. Providing a Sense of Purpose

Criterion A. Conveying unit purpose. Does the material convey an overall sense of purpose and direction that is understandable and motivating to students?

Indicators of meeting the criterion
1. A problem, question, representation (or otherwise identified purpose) is presented to students.
2. The problem, question, representation (or otherwise identified purpose) is likely to be comprehensible to students.
3. The problem, question, representation (or otherwise identified purpose) is likely to be interesting and/or motivating to students.
4. Students are given an opportunity to think about and discuss the problem, question, representation (or otherwise identified purpose).
5. Most lessons are consistent with the stated purpose and those that are not are explicitly labeled as digressions.
6. The material returns to the stated purpose at the end of the unit.

Rating Scheme
Excellent: The material meets indicators 1–6.
Satisfactory: The material meets indicators 1–3 and 5.
Poor: The material meets indicator 1 at best.

Criterion B. Conveying lesson/activity purpose. Does the material convey the purpose of each lesson/activity and its relationship to others?

Indicators of meeting the criterion
1. The material conveys or prompts teachers to convey the purpose of the activity to students.
2. The purpose is expressed in a way that is likely to be comprehensible to students.
3. The material encourages each student to think about the purpose of the activity.
4. The material conveys or prompts teachers to convey to students how the activity relates to the unit purpose.
5. The material engages students in thinking about what they have learned so far and what they need to learn/do next at appropriate points.

Rating Scheme
Excellent: The material meets all indicators.
Satisfactory: The material meets any three out of the five indicators.
Poor: The material meets no more than one out of the five indicators.

Criterion C. Justifying lesson/activity sequence. Does the material involve students in a logical or strategic sequence of activities (versus just a collection of activities)?

Indicators of meeting the criterion
1. The material includes a logical or strategic sequence of activities.
2. The material conveys the rationale for this sequence.

Rating Scheme
Excellent: The material meets both indicators.
Satisfactory: The material meets the first indicator.
Poor: The reviewer can infer a logical rationale for the sequence of only a few activities.

Category II. Taking Account of Student Ideas.
**Criterion A. Attending to prerequisite knowledge and skills.** Does the material specify prerequisite knowledge/skills that are necessary to the learning of the key idea(s)?

Indicators of meeting the criterion
1. The material alerts the teacher to specific prerequisite ideas or skills (versus stating only prerequisite topics or terms).
2. The material alerts teachers to the specific ideas for which the prerequisites are needed.
3. The material alerts students to prerequisite ideas or experiences that are being assumed.
4. The material adequately addresses (provides instructional support for) prerequisites in the same unit or in earlier units (in the same or other grades). (The material should not be held accountable for addressing prerequisites from an earlier grade range. However, if a material does address such prerequisites they should count as evidence for this indicator.)
5. The material makes adequate connections (provides instructional support for connections) between ideas treated in a particular unit and their prerequisites (even if the prerequisites are addressed elsewhere).

**Rating Scheme**

- **Excellent:** The material meets indicators 1, 2, 3 or 4, and 5 for all or most prerequisites.
- **Satisfactory:** The material meets indicators 1, 2, 5, and either 3 or 4 for some prerequisites.
- **Fair:** The material meets indicators 5 and either 3 or 4 for some prerequisites.
- **Poor:** The material meets no more than one indicator.

**Criterion B. Alerting teacher to commonly held student ideas.** Does the material alert teachers to commonly held student ideas (both troublesome and helpful) such as those described in Benchmarks Chapter 15: The Research Base?

Indicators of meeting the criterion
1. The material accurately presents specific commonly held ideas that are relevant to the key ideas and have appeared in scholarly publications (rather than just stating that students have difficulties with particular ideas or topics).
2. The material clarifies/explains commonly held ideas (rather than just listing them).

**Rating Scheme**

- **Excellent:** The material meets indicators 1 and 2 for a considerable proportion of commonly held ideas that have appeared in scholarly publications.
- **Satisfactory:** The material meets indicators 1 and 2 for some commonly held ideas that have appeared in scholarly publications.
- **Poor:** The material meets indicator 1 at best.

**Criterion C. Assisting teacher in identifying own students' ideas.** Does the material include suggestions for teachers to find out what their students think about familiar phenomena related to key ideas before they are introduced?

Indicators of meeting the criterion
1. The material includes specific questions or tasks that could be used by teachers to identify students' ideas.
2. The questions/tasks are likely to be comprehensible to students who have not studied the topic and are not familiar with the scientific vocabulary.
3. The questions/tasks are identified as serving the purpose of identifying students' ideas.
4. The material includes questions/tasks that ask students to make predictions and/or give explanations of phenomena (rather than focus primarily on identifying students' meanings for terms).
5. The material suggests how teachers can probe beneath students' initial responses to questions or interpret student responses (e.g., by providing annotated samples of student work).

**Rating Scheme**

- **Excellent:** The material provides a sufficient number and variety of questions/tasks that meet indicators 1 and 2 and meet indicators 3–5.
- **Satisfactory:** The material provides some questions/tasks that meet indicators 1–4.
- **Poor:** The material provides some questions/tasks that meet indicator 1 or indicators 1 and 2.

**Criterion D. Addressing commonly held ideas.** Does the material attempt to address commonly held student ideas?

Indicators of meeting the criterion
1. The material explicitly addresses commonly held ideas.
2. The material includes questions, tasks, or activities that are likely to help students progress from their initial ideas, for example, by a. explicitly challenging students’ ideas, for example, by comparing their predictions about a phenomenon to what actually happens b. prompting students to contrast commonly held ideas with the scientifically correct ideas, and resolve differences between them c. extending correct commonly held ideas that have limited scope.
3. The material includes suggestions to teachers about how to take into account their own students' ideas.

Rating Scheme
If there is research on commonly held student ideas:
Excellent: The material meets indicators 1 and 2 for a considerable proportion of commonly held ideas that are documented in the literature.
Satisfactory: The material meets indicators 1 and 2 for some commonly held ideas that are documented in the literature.
Poor: The material meets the first indicator at best.

Category III: Engaging Students with Relevant Phenomena

Criterion A. Providing variety of phenomena. Does the material provide multiple and varied phenomena to support the key ideas?
Indicators of meeting the criterion
1. Phenomena are useful in making the key ideas real.
2. Phenomena are explicitly linked to the relevant key ideas.
Rating Scheme
Excellent: The material provides a sufficient number and variety of phenomena that meet indicators 1 and 2.
Satisfactory: The material provides some phenomena that meet indicators 1 and 2.
Poor: The material provides, at best, one phenomenon that meets indicators 1 and 2.

If the benchmark for which the material is analyzed includes several ideas, the reviewers should proceed as follows:
a. Identify the ideas for which there is a content match.
b. Score the treatment of each idea that results from step a. The overall score for this criterion will be the average of the scores for each idea.

Criterion B. Providing vivid experiences. Does the material include activities that provide firsthand experiences with phenomena when practical or provide students with a vicarious sense of the phenomena when not practical?
Indicators of meeting the criterion
1. Each firsthand experience is efficient (when compared to other firsthand experiences) and, if several firsthand experiences target the same idea, the set of firsthand experiences is efficient. (The efficiency of an experience equals the cost of the experience [in time and money] in relation to its value.)
2. The experiences that are not firsthand (e.g., text, pictures, video) provide students with a vicarious sense of the phenomena. (Please note that if the material provides only firsthand experiences, this indicator is not applicable.)
3. The set of firsthand and vicarious experiences is sufficient.
Rating Scheme
Excellent: The material meets all indicators or just indicators 1 and 3 or indicators 2 and 3, if firsthand experiences are not possible.
Satisfactory: The material includes some efficient firsthand experiences and, if several firsthand experiences target the same idea, the set of firsthand experiences is sufficient. When firsthand experiences are not practical, the material provides students with a vicarious sense of the phenomena for some of the experiences that are not firsthand.
Poor: The material includes at best only one efficient firsthand experience or provides students with a vicarious sense of one phenomenon that is not firsthand.
Reviewers should proceed as follows:
a. Identify the key ideas for which there is a content match.
b. Score the treatment of each idea that results from step a. The overall score for this criterion will be the average of the scores for each idea.

Category IV. Developing and Using Scientific Ideas

**Criterion A. Introducing terms meaningfully.** Does the material introduce technical terms only in conjunction with experience with the idea or process and only as needed to facilitate thinking and promote effective communication?

Indicators of meeting the criterion
1. The material links technical terms to relevant experiences that develop the idea as the term is used (rather than just having students learn definitions of terms).
2. The material restricts the use of technical terms to those needed to communicate intelligibly about key ideas.

Rating Scheme
- Excellent: The material meets both indicators.
- Satisfactory: The material fully meets one indicator and partially meets the other.
- Poor: The material marginally meets both indicators at best.

**Criterion B. Representing ideas effectively.** Does the material include accurate and comprehensible representations of the key ideas?

Indicators of meeting the criterion
1. Representation is accurate (or, if not accurate, then students are asked to critique the representation).
2. Representation is likely to be comprehensible to students.
3. Representation is explicitly linked to the real thing.

Rating Scheme
- Excellent: The material includes a sufficient number and variety of representations that meet indicators 1–3 and none of the representations included in the material are inaccurate. (In order to judge whether there is a sufficient number and variety of representations, reviewers should first consider which key ideas require representations and then decide whether these are adequately represented. However, reviewers are not expected to evaluate and rate each idea separately and average the scores.)
- Satisfactory: The material includes some representations that meet indicators 1–3 and few (if any) of the representations included in the material are inaccurate. (In some cases, including one accurate and comprehensible representation for a specific idea may be sufficient for a material to receive a "satisfactory" rating. However, most of the key ideas must be adequately represented.)
- Poor: Even though the material includes a few representations that meet indicators 1–3, few or none of the key ideas are adequately represented.

**Criterion C. Demonstrating use of knowledge.** Does the material demonstrate/model or include suggestions for teachers on how to demonstrate/model skills or the use of knowledge?

Indicators of meeting the criterion
1. The material consistently carries out (or instructs teachers to carry out) the expected performance (e.g., the student text explains a particular phenomenon using the kinetic molecular theory). (Teacher's guides often include responses to questions posed in the student text. If the material does not instruct the teacher to use the answers to model the use of knowledge, such responses do not count as instances of modeling.)
2. The performance is step-by-step.
3. The performance is explicitly identified as a demonstration of the use of knowledge or skill.
4. The material provides running commentary that points to particular aspects of the demonstration and/or criteria for judging the quality of a performance.

Rating Scheme
- Excellent: The material meets all 4 indicators.
- Satisfactory: The material meets indicators 1 and 2.
- Poor: The material meets indicator 1 at best.

**Criterion D. Providing practice.** Does the material provide tasks/questions for students to practice skills or use knowledge in a variety of situations?

Indicators of meeting the criterion
1. The material provides a sufficient number of tasks in a variety of contexts, including everyday contexts. (In order to determine whether the task/question addresses the actual substance of the key idea, reviewers will need to consider both the question and the expected response in the teacher's guide.)
2. The material includes novel tasks.
3. The material provides a sequence of questions or tasks in which the complexity is progressively increased.
4. The material provides students first with opportunities for guided practice with feedback and then with practice in which the amount of support is gradually decreased.

Rating Scheme
Excellent: The material meets indicators 1, 2, and either 3 or 4.
Satisfactory: The material provides some tasks/questions, including novel tasks.
Poor: The material provides at best some tasks/questions, but no novel tasks.

Reviewers should proceed as follows:
- a. Identify the key ideas for which there is a content match.
- b. Score the treatment of each idea that results from step a. The overall score for this criterion will be the average of the scores for each idea.

Category V: Promoting Student Thinking about Phenomena, Experiences, and Knowledge.

Criterion A: Encouraging students to explain their ideas. Does the material routinely include suggestions for having each student express, clarify, justify, and represent his or her ideas? Are suggestions made for when and how students will get feedback from peers and the teacher?

Indicators of meeting the criterion
1. Material routinely encourages students to express their ideas.
2. Material encourages students not only to express but also to clarify, justify, and represent their ideas (a material is not expected to encourage students to clarify, justify, and represent ideas each time they are asked to express their ideas; however, in the course of teaching a particular key idea the material should provide students with opportunities to clarify, justify, and represent ideas).
3. Material provides opportunities for each student (rather than just some students) to express ideas.
4. Material includes specific suggestions on how to help the teacher provide explicit feedback to students or includes text that directly provides students with feedback.
5. Material includes suggestions on how to diagnose student errors, explanations about how these errors may be corrected, and recommendations for how students' ideas may be further developed.

Rating Scheme
Excellent: Material meets all indicators.
Satisfactory: Material meets 3 out of 5 indicators.
Poor: Material meets no more than 1 out of 5 indicators.

Criterion B: Guiding student interpretation and reasoning. Does the material include tasks and/or question sequences to guide student interpretation and reasoning about experiences with phenomena, representations, and ideas?

Indicators of meeting the criterion
1. The material includes specific and relevant tasks and/or questions for the experience or reading.
2. The questions or tasks have helpful characteristics such as
   a. framing important issues
   b. helping students to relate their experiences with phenomena or representations to presented scientific ideas
   c. helping students to make connections between their own ideas and the phenomena or representations observed
   d. helping students to make connections between their own ideas and the presented scientific ideas
   e. anticipating common student misconceptions
   f. focusing on contrasts between student misconceptions and scientific alternatives.

Please note that while a single high quality task or question sequence might have only one of these characteristics, the set of sightings should exhibit several of them.
3. There are scaffolded sequences of questions or tasks (as opposed to separate questions or tasks).

Rating Scheme
Excellent: Material consistently meets all three indicators.
Satisfactory: Material consistently meets indicators 1 and 2.
Poor: Material meets indicator 1 at best.

**Criterion C: Encouraging students to think about what they've learned.** Does the material suggest ways to have students check and reflect on their own progress?

Indicators of meeting the criterion
1. The material gives students an opportunity to revise their initial ideas based on what they have learned (without asking them explicitly to think about how their ideas have changed).
2. The material engages (or provides specific suggestions for teachers to engage) students in monitoring how their ideas have changed, but does so infrequently in the unit.
3. The material engages (or provides specific suggestions for teachers to engage) students in monitoring how their ideas have changed and does so periodically in the unit.

Rating Scheme
Excellent: The material meets indicator 3.
Satisfactory: The material meets indicator 2.
Poor: The material meets indicator 1 at best.

**Category VI: Assessing Progress**

**Criterion A: Aligning assessment to goals.** Assuming a content match between the curriculum material and the key ideas, are assessment items included that match the key ideas?

Indicators of meeting the criterion
1. The specific ideas in the key ideas are necessary in order to respond to the assessment items.
2. The specific ideas in the key ideas are sufficient to respond to the assessment items (or, if other ideas are needed, they are not more sophisticated than key ideas and have been taught earlier).

Rating Scheme
Excellent: The material provides a sufficient number [9] of assessment items that meet indicators 1 and 2.
Satisfactory: The material provides some assessment items that meet indicators 1 and 2.
Poor: The material provides no more than one/a few assessment items that meet indicators 1 and 2.

**Criterion B: Testing for understanding.** Does the material include assessment tasks that require application of ideas and avoid allowing students a trivial way out, like using a formula or repeating a memorized term from the text without understanding it?

Indicators of meeting the criterion
1. Assessment items focus on understanding of key ideas.
2. Assessment items include both familiar and novel tasks.

Rating Scheme
Excellent: The material provides a sufficient number of assessment items that meet indicators 1 and 2.
Satisfactory: The material provides some assessment items that meet indicators 1 and 2 or sufficient assessment items that meet indicator 1.
Poor: The material provides no more than one/a few assessment items that meet indicator 1.

**Criterion C: Using assessment to inform instruction.** Are some assessments embedded in the curriculum along the way, with advice to teachers as to how they might use the results to choose or modify activities?

Indicators of meeting the criterion
1. The material uses embedded assessment as a routine strategy (rather than just including occasional questions).
2. The material assists teachers in interpreting student responses to diagnose what learning difficulties remain.
3. The material provides specific suggestions to teachers about how to use the information from the embedded assessments to make instructional decisions about what ideas need to be addressed by further activities.

Rating Scheme
Excellent: The material meets all indicators.
Satisfactory: The material meets indicators 1 and 2 or indicators 1 and 3.
Poor: The material meets indicator 1 at best.
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Category VII. Enhancing the Science Learning Environment

Criterion A. Providing teacher content support. Would the material help teachers improve their understanding of science, mathematics, and technology necessary for teaching the material?

Indicators of meeting the criterion.
1. The material provides content information for teachers that is relevant to the learning goals they are teaching.
2. The material alerts teachers to how ideas have been simplified for student and what the more sophisticated versions are (even though students are not expected to understand the more sophisticated ideas).
3. The material provides sufficiently detailed answers to questions in the student book for teachers to understand and interpret typical student responses.
4. The material makes suggestions for how to use recommended resources for improving teachers understanding of the learning goals.

Rating Scheme
Excellent: The material meets all indicators.
Satisfactory: The material meets indicator 2 out of the 4 indicators.
Poor: The material meets indicator 1 at best.

Criterion B. Encouraging curiosity and questioning. Does the material help teachers to create a classroom environment that welcomes student curiosity, rewards creativity, encourages a spirit of healthy questioning, and avoids dogmatism?

Indicators of meeting the criterion.
1. The material provides opportunities for students to express their curiosity and creativity.
2. The material provides occasion for students to ask questions and guides their search for answers.
3. The material provides opportunities to respect and value students’ ideas (e.g. by suggesting how each student’s ideas can be heard and considered and held up to evidence).
4. The material sends the message that science is more than rules or facts to be learned and that problems may have more than one solution.
5. The material provides examples of classroom interactions—e.g. dialogue boxes, vignettes, or video clips—that illustrate appropriate ways to respond to student questions or ideas, etc.

Rating Scheme
Excellent: The material meets all indicators.
Satisfactory: The material meets indicator 3 out of the 5 indicators.
Poor: The material meets indicator 1 at best.

Criterion C. Supporting all students. Does the material help teachers to create a classroom community that encourages high expectations for all students, that enables all students to experience success, and that provides all students a feeling of belonging in the science classroom?

Indicators of meeting the criterion.
1. The material avoids stereotypes or language that might be offensive to a particular group.
2. The material illustrates the contribution or participation of under-represented groups to science-related fields.
3. The material suggests alternative formats for students to express or develop their ideas during instruction and assessment.
4. The material includes specific suggestions about modifying activities for students with special needs, interests, or abilities.
5. The material provides strategies to validate students’ personal and social experiences as being relevant to mathematical or scientific ideas.

Rating Scheme
Excellent: The material meets all indicators.
Satisfactory: The material meets indicator 3 out of the 5 indicators.
Poor: The material meets indicator 1 at best.
Appendix B.

List of Evaluation Team Participants for Instructional Analysis

(May 14th-17th, 2003).

Motion and Forces Team

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Adapted from AAAS/Project 2061

The difference in heating of the earth's surface produces the planet's seasons and weather patterns (4B, 6-8, #4). Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year (4B, 6-8, #4).

The earth is one of several planets that orbit the sun and the moon orbits around the earth (4A, 3-5, #4).

To people on earth, this turning of the planet makes it seem as though the sun, moon, planets, and stars are orbiting the earth once a day (4B, 3-5, #2).

The sun warms the land, air and water (4E, K-2, #1). Some events in nature have a repeating pattern. The weather changes from day to day, but things such as temperature tend to be high, low or medium in the same months every year (4B, K-2, #1).

Like all planets and stars, the earth is approximately spherical in shape (4B, 3-5, #2). The rotation of the earth on its axis every 24 hours produces the night-and-day cycles (4B, 3-5, #2).

Seasons

Target Ideas

K-2

3-5

6-8

Things that give off light often also give off heat. Heat is produced by mechanical and electrical machines, and any time one thing rubs against something else (4E, 3-5, #1).

Some changes are so slow or so fast that they are hard to see (11C, K-2, #4).

Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail. (11B, 3-5, #2).

The earth is sun of several planets that orbit the sun and the moon orbits around the earth (4B, 3-5, #4).

Sun, Light, and Heat

Heat can be transmitted through materials by the collision of atoms or across space by radiation. If the material is fluid, currents will be set up in it and the rate of flow depends on the temperature differences (4E, 6-8, #3).

Potential 9-12 Benchmark

Cycles of Planets and Stars

Temperature Change

Some changes are so slow or so fast that they are hard to see (11C, K-2, #4).

Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail. (11B, 3-5, #2).

Figure 2. Map showing the five target ideas, prerequisite ideas, related ideas, and more advanced ideas by grade level.
Table 1. Criterion-level Instructional Analysis ratings for Chemistry That Applies, GEMS: The Real Reasons for Seasons and ARIES: Exploring Motion and Forces.

<table>
<thead>
<tr>
<th>Instructional Analysis Ratings</th>
<th>Chemistry That Applies</th>
<th>ARIES—Exploring Motion and Forces</th>
<th>GEMS—The Real Reasons for Seasons</th>
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</thead>
<tbody>
<tr>
<td>Excellent=₁; Very Good=₀; Satisfactory=₋; Poor=₋</td>
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<tr>
<th>Instructional Categories</th>
<th>Chemistry That Applies</th>
<th>ARIES—Exploring Motion and Forces</th>
<th>GEMS—The Real Reasons for Seasons</th>
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</thead>
<tbody>
<tr>
<td>I. Identifying a Sense of Purpose</td>
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<td>Conveying unit purpose</td>
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<td>Conveying lesson/activity purpose</td>
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<td>Justifying lesson/activity sequence</td>
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<td>II. Taking Account of Student Ideas</td>
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<td>Attending to prerequisite knowledge and skills</td>
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<td>Alerting teacher to commonly held student ideas</td>
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<td>IV. Developing and Using Scientific Ideas</td>
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<tr>
<td>Introducing terms meaningfully</td>
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<td>Representing ideas effectively</td>
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<td>Providing practice</td>
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<td>VI. Assessing Progress</td>
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<td>Aligning assessment to goals</td>
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<td>VII. Enhancing the Science Learning Environment</td>
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<tr>
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