Appendix H

Grades 9–12 Science

Typical Lessons

Ratings of Lesson Components

Overall Lesson Quality

Typical Lessons

The following lesson descriptions are based on a random sample of 9th–12th grade science lessons.

9th Grade Biology: Review for End-of-Grade Exam

The 9th grade class has been working on a review for the end-of-grade, district-wide common exam in biology. Prior to beginning this review, which was scheduled to last two weeks, the class was working through the different kingdoms of living things. The teacher developed the lesson using two textbooks, which were not designated by the district, but that he believed were better suited to the reading levels of the students.

The lesson had two parts. In the first 20 minutes of the class, the teacher gave detailed directions for completing a class assignment to make a model of a plant or animal cell out of materials of their choice. For the remainder of the lesson, the teacher outlined the requirements to pass biology and conducted a question and answer session on topics that would be on the end-of-grade test: osmosis, diffusion, classification. A typical exchange was as follows: The teacher asked the class to turn to page 83 in their text which had a picture of ink drops being put in water until equilibrium was reached. He asked a student to read the caption under the picture which explained what was happening. When she finished the teacher asked, “Who wants to define equilibrium?” Another student raised her hand and read the definition from the book. The teacher gave the example of spraying perfume on one side of the room to illustrate diffusion. He also used the example of dye to color eggs at Easter. The teacher told the class, “I guarantee that there will be a question on the test about osmosis and diffusion. If you see passive transport on the test you know it is diffusion.” Similar exchanges occurred with the other topics being reviewed. The lesson ended with the teacher giving students tips on taking tests.

9^{th} Grade Earth and Environmental Sciences: Analyzing Nutrients in Soils

This 9^{th} grade lesson came near the beginning of a unit on soil and water testing. It focused on analyzing nutrients in soil from the local community, in many cases from students' gardens. The teacher indicated that soil was a key link between earth and environmental science, and that this lab gave students the chance to see how science is applicable to their lives (by testing soil from their own homes and figuring out what types of plants they could grow).

The lesson began with the students taking a short quiz on background reading from the night before, focusing on the effects of the various soil nutrients on plant growth and development. After taking the quiz, students swapped and graded the quiz as the class reviewed the answers. Next, the teacher distributed the lab instructions and spent about 15 minutes giving students some hints on how to complete the lab (such as making sure they used the correct scoop when measuring the chemicals as there were two that looked the same but held different amounts).

The class spent the remainder of the period working on the soil tests, measuring the pH, and the concentrations of nitrogen, phosphorous, and potassium. Because of the amount of time needed to complete all four tests, the teacher planned for students to complete half of the tests during this lesson and finish the remaining ones the next day. The students were engaged with the activity and were concentrating on carrying out the procedures correctly. During the lab work, students discussed the proper procedures (e.g., how long they had to wait for the mixtures to settle, how much indicator they had to add). While the groups were working, the teacher circulated and assisted students when necessary, answering questions about the procedures. Most groups finished 2 of the 4 tests (as the teacher planned), though some completed 3. The teacher wrapped up the lesson by telling the students they would finish the tests the next day and then analyze and discuss the data.

9th Grade Physical Science: Atomic Models

This lesson was an introduction to atomic structure. After taking attendance, the teacher handed back the students' tests from the previous chapter so that students could see their grades. The teacher then collected the tests and told them that they were going to start on Chapter 5. He said, "Chapter 5 is on atomic structure, so the first thing we'll do is look at models." After briefly explaining models, he instructed students to use their textbooks to take 3–4 sentences of notes on each of the six models: Greek model, Dalton's model, Thomson's model, Rutherford model, Bohr model, and the Wave model. He said, "Just go through your book and give me 2, 3, or 4 sentence descriptions of these models." Further, he told students that he would be out the next two school days so this was just an introduction. The teacher said, "Basically what I'm trying to accomplish is to get the idea in your head. Then on Monday we'll basically start over, knowing you will forget this in two days, I'm sure. I'll try to line you up for a video when I'm gone."

The teacher lectured briefly on the six models before assigning a worksheet involving the use of their textbook to find factual information on atomic models. After the students completed the worksheet, the teacher called out the answers and then collected the worksheets. The teacher then did another mini-lecture, reviewing what had been covered on the worksheet. This was followed by the teacher talking about diagramming atoms. At one point, he drew a lithium atom on the board, told students the atomic number was 3 and mass number 7, and asked them how many protons were contained in the atom. After a number of attempts, the students finally offered 3, as an answer, but were unable to answer when the teacher asked how many neutrons were in the atom, so he provided the answer, 4. After several similar exchanges, the teacher ended the lesson by just stopping, and students sat talking for the last 10 minutes of the class.

9th Grade Physical Science: Demonstrations of Wave Phenomena

This 9th grade physical science class had just finished two chapters—on sound waves, and colors and light—in their state-adopted textbook. The teacher indicated that he usually provided some sort of lab/demonstration activity at the conclusion of a chapter from the textbook, in this case, at the conclusion of two chapters. The teacher had prepared a series of demonstrations of mechanical waves, polarized light, and colored light.

At the beginning of this 55-minute lesson, students were told to take notes in their notebooks as they watched the demonstrations. The first demo involved a long spring stretched along the central area of the room. He used the spring to demonstrate horizontal and vertical waves, nodes, pulses, interference, and compression waves, one right after the other. This was followed by a series of demonstrations involving light waves. The teacher drew a picture on the board of light waves, blocked in one direction by a horizontal slit and asked students questions about the diagram: "This is called polarization....Is it possible to polarize light? How?" This type of questioning continued with the next demonstration of polarization using sunglasses placed on an overhead projector and a small square of Polaroid filter. The teacher then moved quickly on to show how certain minerals naturally polarize light using a crystal of Iceland spar and then mica placed on the overhead projector sandwiched between two sheets of Polaroid film. He asked the students to predict what would happen if he rotated the top piece of film and then showed them that only the center remained light. The teacher next showed on the overhead how polarized light could be used to find stresses in materials, like plastic, using X-rays. The topic for the demos once again shifted, this time to sound. The teacher rapidly performed demos showing how the vibrations from one tuning fork can make another tuning fork vibrate, but only when both are "playing the same note." The last ten minutes of class were spent on several demonstrations with different colors of light. Again using the overhead, the teacher reviewed how different colored filters could be used to combine magenta, cyan, and yellow to all of the other colors. The class ended with a reminder that they had two days remaining to prepare their projects for the science olympics.

9th–10th Grade Biology: Evolution

This was the final lesson in a unit on evolution. The students had previously learned about fossils and the geologic time scale, as well as Lamarck's and Darwin's theories of species change.

The teacher began the lesson with a review, asking a series of questions such as: "What was the first piece of evidence for evolution? Who remembers what epoch we live in? What was Lamarck's theory of evolution? Why did Darwin say [giraffes'] necks get long?" Next, the teacher told students to open their texts to the appropriate page, and placed an outline on the overhead projector. For the next thirty minutes she lectured based on that outline. She gave five modern pieces of evidence for evolution by natural selection: analogous structures, homologous structures, vestigial organs, similarities of embryos, and macromolecules. She provided examples for each (from the textbook) and asked questions throughout, such as "What do you notice about these diagrams (of arm bones of different mammals)?" "Can anyone think of an organ inside the body that today is not used?" and "What does a nucleotide consist of?" When directly called to do so, students answered questions, but otherwise spent most of their time copying the teacher's outline into their notes. The teacher next turned her lecture to the subject of evolutionary patterns listing three types: coevolution, convergent evolution, and divergent evolution. She drew diagrams and gave examples for each.

9^{th}–12^{th} Grade Environmental Science: Alternative Energy Sources

This lesson was a review of previous discussions and lectures, focusing on alternative energy sources. The teacher reported that for this course, he is required to follow the district's Earth Science standards because there are no environmental science standards. Also, he said that he is required by the district to use the textbook and resource materials provided for the course.

At the start of the lesson, the teacher reviewed the previous day's activity (measuring soccer/football fields and bleachers). He did this by asking students to call out their measurements and then wrote the correct measurements on the board. The teacher told students to bring gardening gloves for the next class for they would be doing work on the school grounds.

The remainder of the lesson consisted of students calling out answers to a five-page packet, where each page was a section review for a particular section of Chapter 17 in their text. For example, the first page of the packet consisted of seven questions such as: "People burn fossil fuels and use both wind and water to generate electrical power. Explain how the energy in all of these sources originates from the sun's energy." and "What is active solar heating? Provide some examples." The questions in the other section reviews covered hydroelectric power, wind energy, and geothermal energy. The last page of the handout was titled "Vocabulary Review" and required students to use a dictionary to write definitions for words used throughout these sections (e.g., solar energy, photovoltaic cell, geothermal energy).

Near the end of the lesson the teacher said, "I guess this will be the last one we'll do" and then called on a student. The student started answering the question, but the announcements came on, so she stopped and everyone packed up and left the room.

10th Grade Biology: Natural Selection and Adaptation

Students in this 10th grade biology course had been studying evolution. They had recently watched a video about speciation in finches and had discussed the classic example of adaptation—the industrial melanism in peppered moths in Manchester, England. The class period started with the students working on a "warm-up" activity. They worked individually at their desks to write down the answers to five questions written on an overhead. Examples included: Paleontologists: scientists who study______. Punctuated gradualism: a model of evolution in which periods of ____ change are separated by periods of little or no change. After five minutes the teacher went over the questions with the whole class by reading each question aloud and then calling on a student to give the word to fill in the blank.

Next, the students worked on a lab activity (Peppered Moth Survey) that was designed to simulate the adaptation of peppered moths to industrial melanism. A lab handout directed students to simulate the predator-prey relationship by picking a mixture of two colors of paper discs (white and newspaper) off of two different colors of background paper (white and newspaper). They had 30 seconds to pick up the discs; they were to work in pairs, with one person serving as the timekeeper and the other as the predator. Students graphed the data designated on the lab handout and answered some questions about the two activities. Several students finished early and started working on their homework for this class—answering questions in the textbook.

10th Grade Biology: Protein Synthesis

This lesson came near the end of a required 10th grade trimester biology course focusing on cells and molecular biology. The class had already covered cell processes like photosynthesis, respiration, mitosis, meiosis, and this lesson was an introduction to how genes code for proteins. This topic, according to the teacher, is important for students in this course and is consistent with the required state curriculum.

The twelve students in the class were assembled around a collection of lab desks positioned "conference-style" in the center of a large classroom. Two "Essential Questions" were written on the board for students to copy into their notebooks: (1) "What makes you who you are?" and (2) "How do genes code for proteins?" After everyone had copied the questions, the teacher began an interactive lecture related to those questions. The atmosphere was very informal and relaxed as the teacher, who was sitting at the conference table with the students, described how DNA from within a nucleus codes for the synthesis of particular proteins elsewhere in a cell. During the lecture, the teacher frequently posed questions (e.g., "Do you remember what Mendel found out with his pea plants?"), sometimes making connections between the lesson and students' lives (e.g., "What kind of codes do you encounter in your everyday lives?"—to which a discussion of musical sheet music ensued). The lesson ended with an activity where students acted out the process of protein synthesis using laminated cardboard manipulatives representing DNA, mRNA, and tRNA. The activity to physically model the process came from a colleague a few years prior, and the teacher felt that this activity helped students remember the process because it got them up and out of their seats. At the conclusion of the class period, the teacher indicated that these same essential questions would be addressed in the following lesson as well.

10^{th}–12^{th} Grade Physics: Electrostatics, An Introduction to Electricity

This lesson on electrostatics was the first in a unit on electricity. Although the teacher indicated that the content of this unit is in the district curriculum and on the end-of-level test, the primary purpose of this initial lesson was to introduce the topic through inquiry, exploration, and discussion.

The class began with a "bell quiz," asking students to define the words electrostatics, conductor, and insulator. After reminding students that electrostatics phenomena are familiar to them (the shock you get after scuffing your shoes, your hair sticks out when rubbed with a ballon), the teacher distributed a "Guide Sheet on Electricity," containing the objectives for the upcoming unit as well as lists of the vocabulary, activities, and assignments.

The teacher introduced the day's activity with a brief discussion of charge and then moved the class to a large central open meeting area at the school for an exploration of static electricity using a Van de Graaf generator, Tesla coil, and fluorescent light tube. The teacher explained how each worked and arranged a set of experiments, using students in the class to demonstrate (sometimes a bit painfully) what happens when electrons are pulled from one source to another. During the demonstrations, the teacher explained in a general way what was happening as they tried different arrangements of students and apparatus and watched the "shocking" results. After the initial demonstrations and "zappings," students started to ask a series of "what if…" questions, e.g., "What if I turned it off while holding it?" to which the teacher responded, "What would you predict?" The student came back with, "I'd get a shock!" and the teacher asked, "Why?" The teacher also allowed the students to do some of their own experiments. For example, at their own request, the students made a human chain and all become involved as their hair began to rise and they felt the tingle. The student on the end was the only one who got a shock.

The teacher moderated a whole-class discussion back in the physics classroom of phenomena observed through the explorations and demonstrations. A discussion ensued after several students asked why the spark from the ball was blue but the spark from the coil was purple and what the color of lightning was. The teacher concluded the lesson by telling students what to expect in their study of electricity and by relating what they would be learning to local concerns.

11th Grade Advanced Chemistry: History and Development of the Periodic Table

The class has just finished a study of electron configurations related to the placement of elements in the Periodic Table. This lesson was the first on the history and development of the Periodic Table, a topic specified in the district's curriculum that would be assessed on an end-of-quarter, district-wide test.

The session began with about 10 minutes of non-instructional activity—the teacher taking care of paperwork and the students "getting ready for a pop quiz" (mostly just talking). The pop quiz consisted of five questions designed to see which students had read the chapter, an assignment given the previous day by a substitute teacher. The teacher collected the papers, commenting, "If more than half the class fails the quiz, then we won't count it, but the next one will." The teacher went over the questions, with students calling out the answers.

The next component of the lesson was essentially that of the teacher reading through and elaborating on an outline of facts in the chapter (names, contributions, vocabulary) that had been typed on a transparency, while the students took notes. About halfway through the class period, the teacher stopped the note-taking and passed out section review sheets that students had completed the previous day. Students graded each others' papers, with the teacher giving the instruction, "Mark it wrong if they miss it, but don't correct it. They can look it up, might learn something." The teacher asked for answers to each of the questions on the worksheets which consisted of multiple choice and short answer items.

For the remainder of the lesson, the teacher instructed the class to work on questions 1–30 in their Chapter 5 study guide.

11^{th}–12^{th} Grade AP Chemistry: Buffers and LeChatelier's Principle

This lesson was the first in a unit on equilibrium and was meant to have the students apply their prior knowledge of pH and equilibrium to buffers and salts. As a part of the unit, the teacher planned lessons on buffers and titration, including pH and LeChatalier's principle, concepts the teacher indicated students need to learn in order to do well on the AP test and for further study of chemistry in college.

The lesson began with the teacher distributing a handout (an outline and some sample problems) and asking students to solve the first problem as a review (calculating the pH of 3.0 M $HC_2H_3O_2$ with Ka = 1.8E–5). The teacher then reviewed the solution, asking students to tell her how to determine the pH. She then asked the students to apply LeChatelier's Principle and how adding acetate to the system would affect the pH. Most of the remainder of the lesson was spent with the teacher lecturing on buffers, asking the class questions such as "What are the products of dissociation [of acetic acid]?" "What would happen [to the equilibrium of this reaction] if we added tons of acetate?" "What happens to an acid or base when you add it to a buffer?" and doing sample problems (calculating the pH of acetic acid). Towards the end of the class, the teacher assigned homework and asked the students to begin it in the time remaining.

11^{th}–12^{th} Grade Zoology: Cnidarians (Jellyfish)

The students had just completed a unit test on cnidarians and were ready to begin a review for their upcoming semester exam. The lesson consisted of two main components: a PowerPoint presentation on cnidarians and a lab in which students studied a living cnidarian.

The teacher began the lesson by congratulating the students on a job well done on their test on cnidarians. She informed the class that after today's lesson they would begin preparing for their semester exam. The teacher then presented a PowerPoint presentation on cnidarians and informed the class that it was a review of material from their previous unit test. The students sat quietly and listened as the teacher talked through numerous professional quality, colorful slides for about an hour.

At the conclusion of the presentation, the teacher passed out a hand-written worksheet and told the students to work in pairs to observe a live jellyfish, the Gonionemus. Students were instructed to each answer the four questions on the worksheet and draw and label the parts of their specimen on the back of the worksheet. Students moved efficiently to their lab stations while the teacher passed out the specimens in wet petri dishes, and within a few minutes, students were "oohing" and "ahhing" over their jellyfish. Students were actively observing, but did little writing and recording. When the bell rang, the teacher told the students to finish the worksheet for homework.

Ratings of Lesson Components

The designs of high school science lessons are, on average, rated most highly for the contribution of available resources to accomplishing the lessons' goals and for careful planning and organization. Somewhat fewer lesson designs take students' preparedness into account. The lessons are weakest in providing adequate time and structure for wrap-up. Synthesis ratings for design are low for 60 percent of lessons, medium for 29 percent, and high for 11 percent.

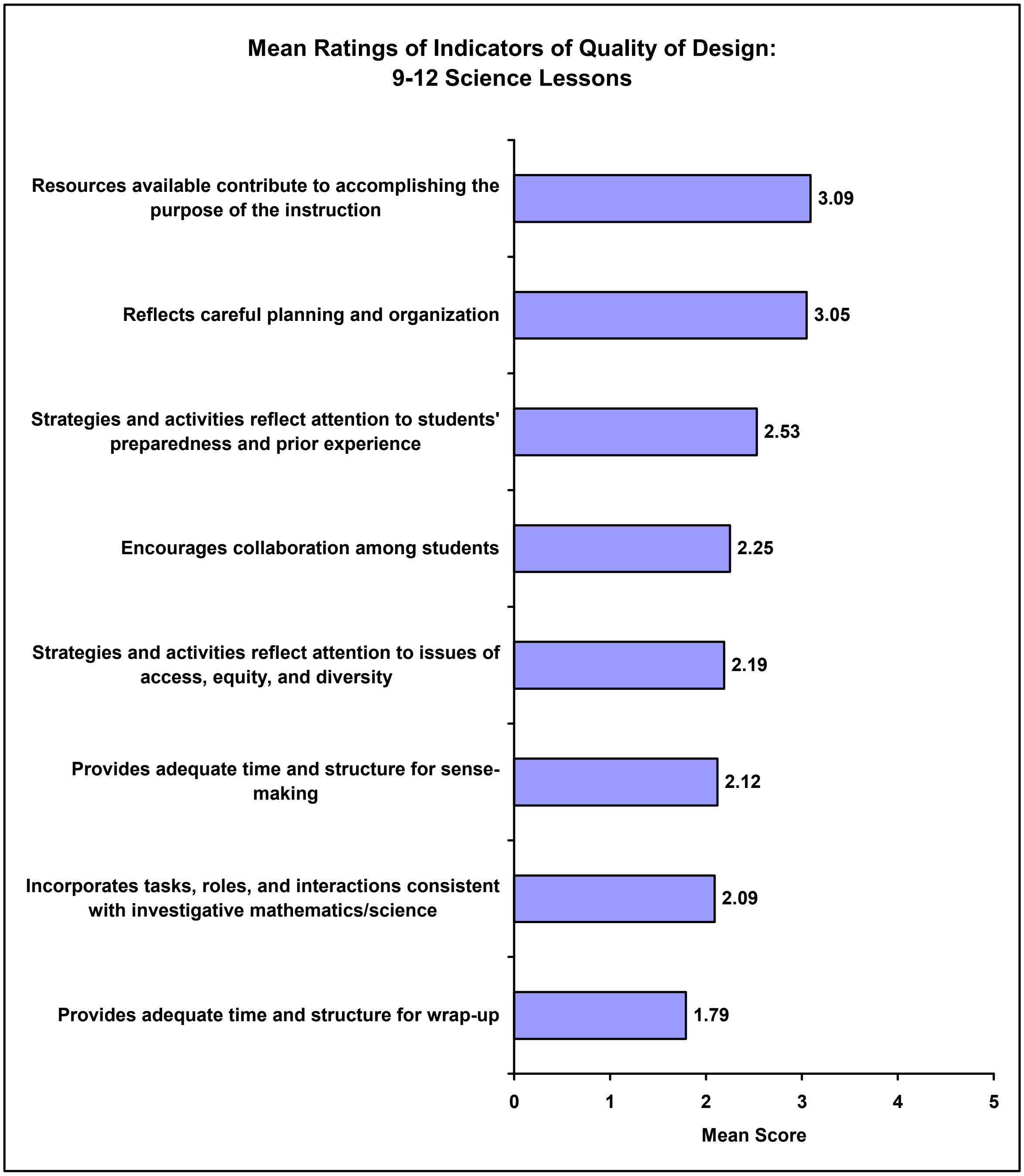

Mean Ratings of Indicators of Quality of Design:
9-12 Science Lessons
Resources available contribute to accomplishing the purpose of the instruction
3.09
Reflects careful planning and organization
3.05
Strategies and activities reflect attention to students' preparedness and prior experience
2.53
Encourages collaboration among students
2.25
Strategies and activities reflect attention to issues of access, equity, and diversity
2.19
Provides adequate time and structure for sense-making
2.12
Incorporates tasks, roles, and interactions consistent with investigative mathematics/science
2.09
Provides adequate time and structure for wrap-up
1.79
0
1
2
3
4
5
Mean Score

Figure H-1

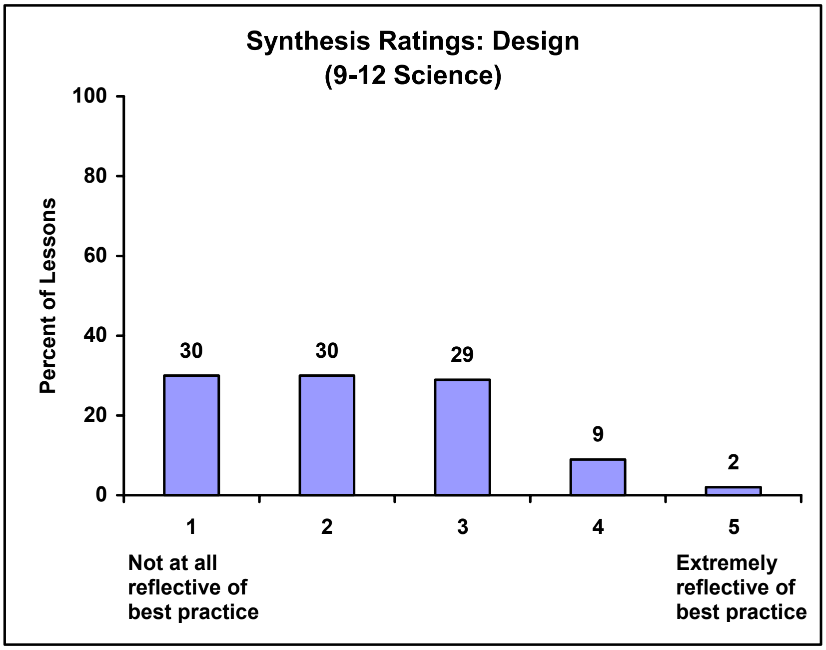


Figure H-2

Teacher confidence is, on average, the strongest aspect of high school science implementation. Teachers' classroom management is ranked somewhat less highly. The lowest-ranking aspects of implementation are the use of investigative instructional strategies and teacher questioning. The relatively low rankings in these areas may contribute to the low synthesis ratings of 74 percent of lessons. Twelve percent are ranked medium, and only 14 percent receive high ratings for implementation.

Mean Ratings of Indicators of Quality of Implementation: 9-12 Science Lessons

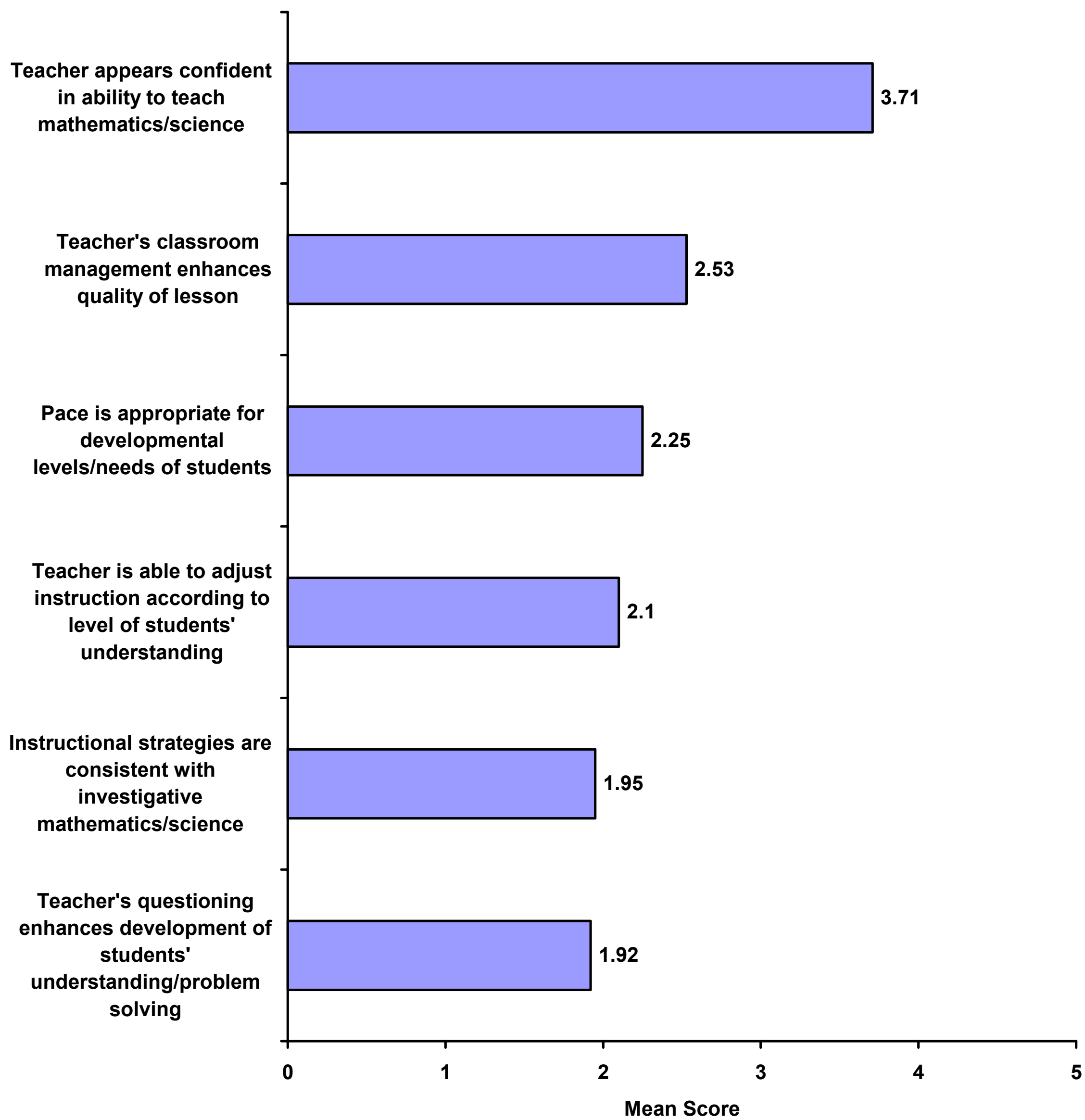


Figure H-3

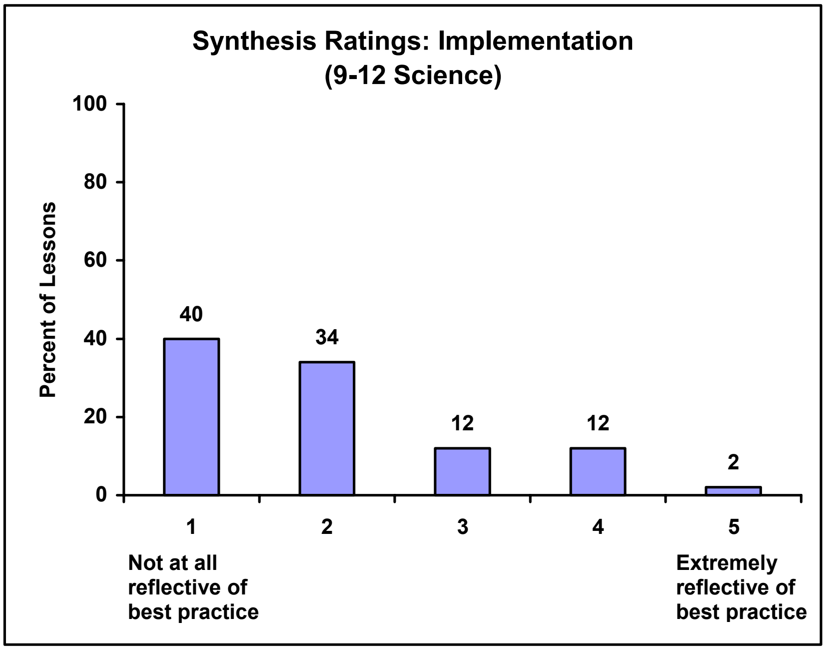
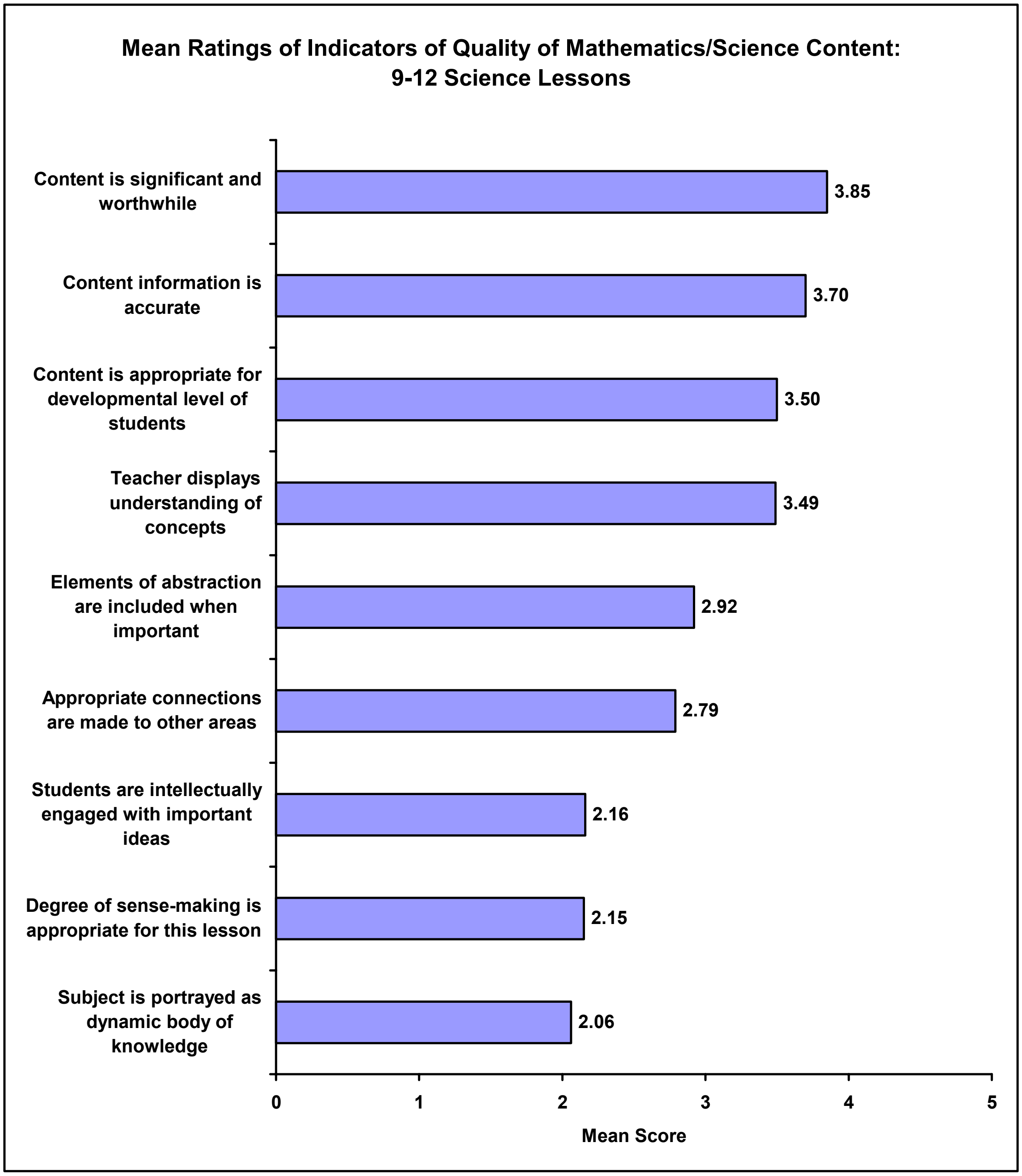


Figure H-4

High school science lessons are rated highly for significant, worthwhile, and developmentally appropriate content, as well as for teachers' clear grasp of the concepts being taught. Weaker points include a lack of intellectual engagement by students and a low degree of sense-making. In addition, lessons tend not to portray science as a dynamic body of knowledge. Synthesis ratings for content are low for 58 percent of lessons, medium for one-fourth, and high for 18 percent.



Mean Ratings of Indicators of Quality of Mathematics/Science Content:
9-12 Science Lessons
Content is significant and worthwhile
3.85
Content information is accurate
3.70
Content is appropriate for developmental level of students
3.50
Teacher displays understanding of concepts
3.49
Elements of abstraction are included when important
2.92
Appropriate connections are made to other areas
2.79
Students are intellectually engaged with important ideas
2.16
Degree of sense-making is appropriate for this lesson
2.15
Subject is portrayed as dynamic body of knowledge
2.06
0
1
2
3
4
5
Mean Score

Figure H-5

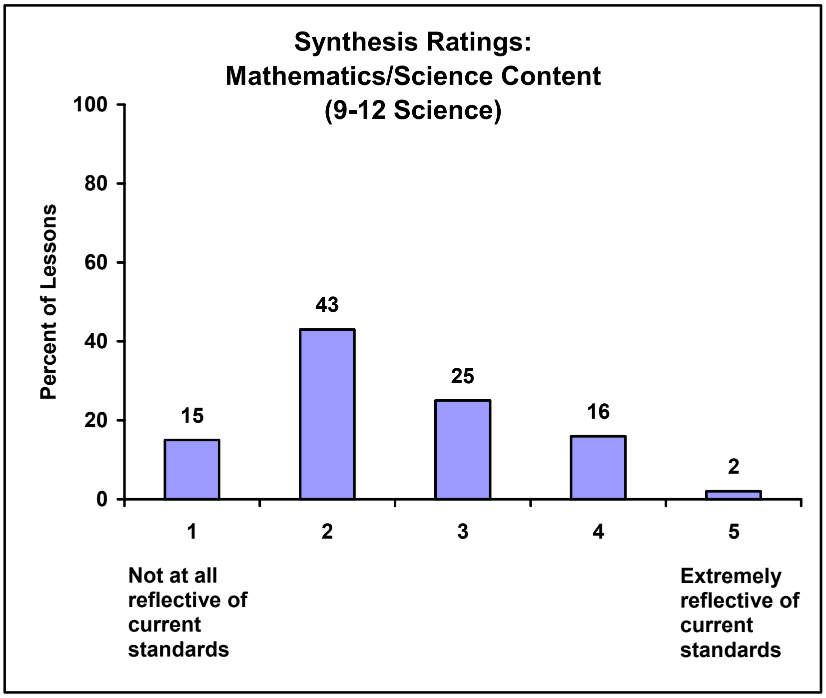


Figure H-6

On average, high school science lessons are rated higher for including a climate of respect than for other aspects of culture. Lessons tend to be weak in encouraging students to generate ideas and questions, and intellectual rigor is not often evident. These limitations may contribute to the low percentage of lessons receiving high synthesis ratings (13 percent, compared to 21 percent medium and 65 percent low).

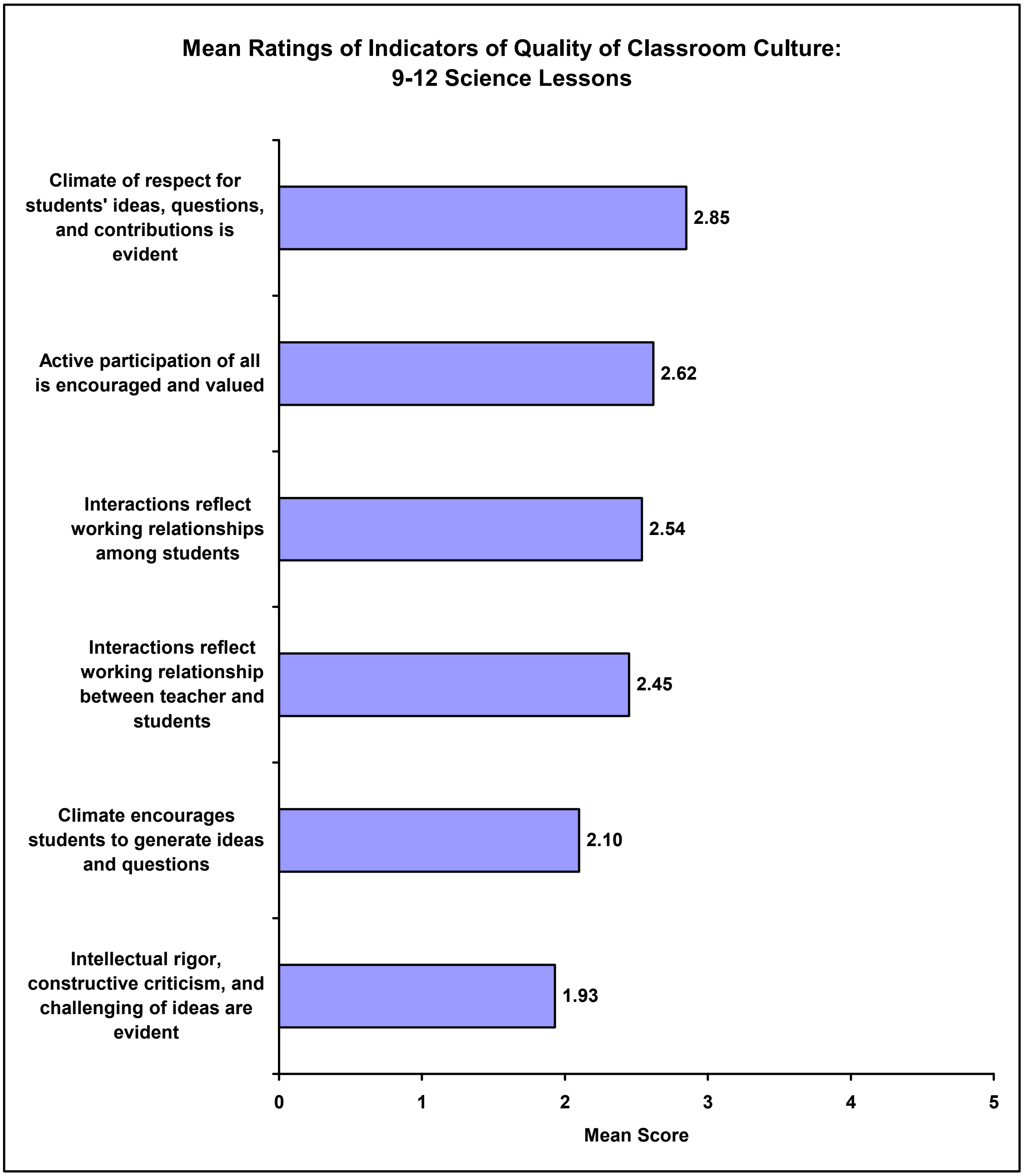

Mean Ratings of Indicators of Quality of Classroom Culture:
9-12 Science Lessons
Climate of respect for students' ideas, questions, and contributions is evident
2.85
Active participation of all is encouraged and valued
2.62
Interactions reflect working relationships among students
2.54
Interactions reflect working relationship between teacher and students
2.45
Climate encourages students to generate ideas and questions
2.10
Intellectual rigor, constructive criticism, and challenging of ideas are evident
1.93
0
1
2
3
4
5
Mean Score

Figure H-7

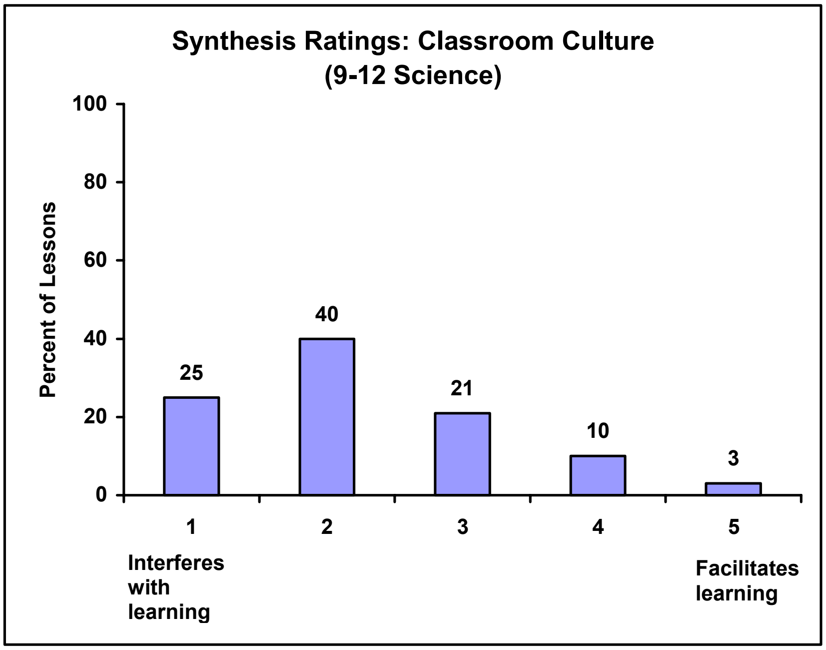

Synthesis Ratings: Classroom Culture
(9-12 Science)
Percent of Lessons
100
80
60
40
20
0
25
40
21
10
3
1
2
3
4
5
Interferes with learning
Facilitates learning

Figure H-8

Overall Lesson Quality

Following the ratings of the individual components of the lesson, the researcher was asked to consider the likely impacts of the lesson as a whole. Thirty-eight percent of lessons have a positive effect on students' content knowledge, and less than one-fourth of lessons are judged to have a positive effect on other aspects of student learning. Thirty-seven percent of lessons negatively affect students' interest in science. (See Table H-1.)

Table H-1
Likely Ratings of the Lesson: Science 9–12

	Percent of Lessons		
	Negative Effect	Mixed or Neutral Effect	Positive Effect
Students' understanding of important mathematics/science concepts	14	48	38
Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations	14	63	23
Students' self-confidence in doing mathematics/science	24	60	16
Students' interest in and/or appreciation for the discipline	37	47	16
Students' capacity to carry out their own inquiries	18	69	14
Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation	33	55	12

Figure H-9 shows the percentage of 9^{th}–12^{th} grade science lessons in the nation rated at each of a number of levels. (See page 9 of the Observation and Analytic Protocol in Appendix A for a description of these levels.) Sixty-six percent of high school science lessons are rated as low in quality on the capsule rating, 22 percent are rated as medium in quality, and 12 percent are rated as high in quality.

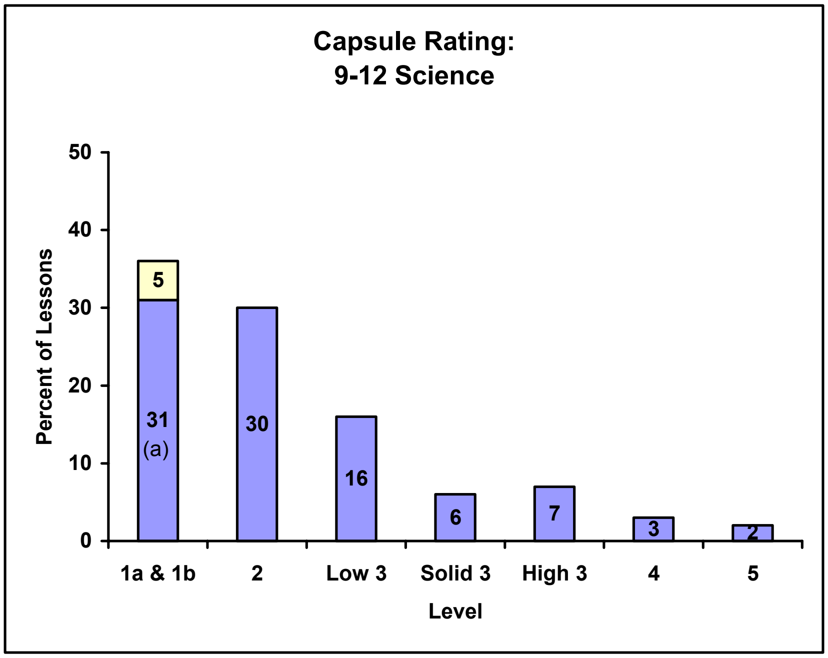


Figure H-9

The following illustrate lesson descriptions that were rated low, medium, and high in quality.

Sample Low Quality Lesson: Passive "Learning"

This 9th grade Biology class was near the end of a unit on evolution. The students had previously studied the formation of the solar system, bacteria and cellular evolution, and changes in the atmosphere over time. After this lesson they would briefly study human evolution, then take a test.

The lesson began with students individually filling out a worksheet on which facts from the chapter were written. Without looking in the book, students had to decide whether the statements were true or false and correct the false ones. The true/false statements included: "Eubacteria was the first bacteria formed." "Multicellular organisms evolved from protists." and "Arthropods invaded land first." Once they had finished working individually, students were instructed to check their work in the book, working in small groups to come to a consensus on the answers, and to document on what page and paragraph they found the answer.

When they had finished the worksheet, the students copied from the board a timeline of evolution that focused on bacteria. Then the teacher announced the answers to the worksheet questions. About half the class did not try to answer the questions in the time allotted but instead waited until the teacher gave out the answers. Some students raised their hands and asked about items they did not understand, in which case the teacher would ask the class to explain the answer, but he rarely gave them time to speak before answering himself. Once students had asked their questions, the teacher read through each worksheet problem one more time and asked students to identify the page and paragraph in which they had found the answer.

The teacher then gave a lecture based on the chapter students had just read. He began by asking students to look at the inside of the textbook's back cover, which showed a chart of the evolution of all life and when each life form was found. He told students that this chart summarized the material they were about to cover. The rest of the lecture consisted of a series of names of organisms and time frames of their existence. The focus was on lists of facts taken from the book; at several points, the teacher read straight out of the textbook or asked students to do so. He introduced new topics by saying, "Next they start talking about continental drift" or "Then it starts talking about sharks." Students followed along in the book. The teacher instructed them to take notes in a two-column format in which one column was titled "Main Themes" and the other was "Detail." Only a few students followed this format, and the teacher never followed through or helped to identify the "Main Themes."

The teacher's questions rarely required higher order thinking, never drew on previous knowledge or real-world connections, and never offered enough wait time for students to consider an answer. Most questions required factual recall and encouraged students to hunt through the text. With fifteen minutes left in class, students were given time to work on homework.

The process of evolution is important and relevant content for 9th graders, and the evolutionary timeline is useful as an organizing context to tell the story of the history of life on Earth. However, in this lesson the information was presented as a series of disconnected facts with no underlying context or relevance to students' lives.

Sample Low Quality Lesson: "Activity for Activity's Sake"

Ninth graders at this school are required to take physical science, but this particular section was labeled as honors, and students had self-selected into it. The class was in the middle of a unit on chemical change, and they had completed a lab in the previous week involving a sulfur and iron reaction. Apparently, there had been complaints from other teachers about odors associated with the lab, and the principal had requested that the lab be discontinued in the future. At the beginning of class, the teacher informed the students about the complaints and a few students stated that they had thought the lab was useful. At that point the teacher set the entire class to the task of writing a "persuasive essay" to the school's principal in support of the lab. Students composed their letters independently using word processors, some spending in excess of 50 minutes on the task. When students had completed their letters, they printed them, submitted them to the teacher, and began work on a two-page, teacher-generated, multiple-choice test. If time permitted, students were to begin working on a laboratory activity designed by the teacher to investigate a chemical reaction that produces heat. Throughout the lesson the teacher engaged in informal and distracting conversations with a few of the students about how the school's athletic teams had been performing lately.

Students worked independently of one another throughout the period in this highly informal atmosphere. The teacher demonstrated respect for this particular class of students in asking them to write the essays and allowing them to pace themselves on each component of the lesson. Unfortunately, the students worked inefficiently on the writing task, and the teacher did very little to help move students forward.

The only science content that can be evaluated is what appeared on the multiple-choice test and on the lab handout. The test questions focused heavily on factual recall related to chemical reactions. The level of difficulty was roughly appropriate, however, and the content was accurate. The lab focused on the scientific process and on logical reasoning. The lab was interesting in that students were instructed to mix multiple reactants, note the generation of heat, and then devise their own experiment to determine which of the reactants were responsible for generating the heat. Given that only one student actually began the lab, however, and that she had only 10 minutes to get started on it, the lab turned out to be at most a modest component of the lesson. Overall, this lesson lacked focus and intellectual rigor.

Sample Medium Quality Lesson: Beginning Stages of Effective Instruction

This lesson came at the end of a unit on the circulatory and respiratory systems. The class had spent three class periods on the circulatory system and this was the third and final class on the respiratory system. (The school was on a block schedule and each class was 90 minutes long.) This lesson had several purposes: to inform students of the dangers of smoking; to discuss various respiratory diseases; to review the Bohr effect; and to discuss the function of the respiratory control center. It appeared that about half of the material was new to students and half was review. Much of the information, while presented in a real world context, was very factual in nature.

The teacher used a variety of instructional materials in this lesson. These included the use of a laserdisc to illustrate the parts of the lungs, an audio tape with the breathing of people with various respiratory diseases, and a laboratory activity and pre-test review worksheet from the textbook package.

The lesson began with the teacher reviewing the Bohr effect and the function of the respiratory control center and then moving into a presentation on different respiratory diseases (lung cancer, emphysema, etc.) and how these diseases worked (e.g., cancer was the out of control reproduction of cells) and the dangers of smoking. The portion on smoking was presented in a very sermon-like manner, with the teacher telling the students how stupid it is to smoke. This entire segment of the class consisted mostly of the teacher talking to the students, occasionally showing a laserdisc picture of the lungs.

After the lecture, the teacher played an audiotape of people with different respiratory diseases breathing, during which the teacher pointed out the associated diseases. This activity engaged most of the students, but it was difficult to differentiate the different sounds and the length of the activity turned this into “let’s laugh at the funny breathing sounds.” In addition, there was no mechanism (or expectation) for the students to record any observations or relationships between the various diseases and breathing sounds. While this activity was fun for the class, it did not add to the students’ understanding of the respiratory system or of respiratory diseases.

The class then completed a breathing rate lab to illustrate how the respiratory control center functioned. Each student measured his/her breathing rate at rest; the class then went to the gym to jump rope and measure their breathing rates after exercise. While the teacher dictated the procedures, the lab was still exploratory in that the students were discovering the relationship between the variables, not simply confirming information they previously learned in class. After collecting the data, the class returned to the classroom and completed the analysis questions on the lab worksheet (which combined concepts from a portion of the activity completed on a previous day regarding the chemical composition of inhaled and exhaled air with the breathing rate exercise). These questions were higher-order as they required students to analyze their data and combine concepts across the portions of the lab activity. However, instead of letting the students complete the worksheet by themselves, or collaboratively, the teacher led the class through the questions, either calling on one student very quickly to give the answer to the class or just giving the students the answers himself.

The teacher then reviewed what would be on the test the next day.

This lesson was rated a low 3, Beginning Stages of Effective Instruction. The teacher-presented information was accurate, but the level of student engagement was highly variable. There was no mechanism to help the students tie together the individual components, and the lesson seemed to jump from one topic to the next without giving students an opportunity to see how it all fit together.

Sample High Quality Lesson: Traditional Instruction

Prior to this lesson on acid-base equivalents, this high school chemistry class had been introduced to titration. The purpose of this lesson was to teach the concept of equivalence and to begin preparation for the titration lab they would encounter in a chemistry contest later in the year.

The 90-minute lesson began with a short review of acid-base reactions and how to create and balance a chemical equation describing such reactions. The class then had a quiz on this material, in which students solved acid-base reaction problems that required indicating the products of the reactions and balancing the chemical equations.

After the quiz, the teacher introduced the concepts of acid-base equivalencies and gram equivalent mass. In the lecture, the teacher gave examples of equivalencies and related the content back to material previously studied by the class, such as acid-base reactions, molarity, and normality. He wrote down definitions and examples on the board. At the end of the lecture, the teacher led the students through a few problems similar to what they had done in prior classes and on the quiz, but using the concept of equivalencies to solve them instead. The students were attentive and clearly engaged.

After the lecture, the class moved into the lab room next door to practice pipetting for the titration lab they were to begin next time they met. The teacher had introduced the lab in a previous lesson, so the students were familiar with the equipment and understood why they needed to practice this skill. The students had about 10 minutes to practice and then were asked to individually demonstrate mastery of this skill to the teacher by using the pipette effectively three times in a row.

This lesson successfully built on and reinforced prior concepts covered in this course, and likely helped deepen the students' understanding of acid-base reactions. The lesson design followed a traditional format (review prior knowledge, introduce new concepts, guided practice), with the students and teacher working together to make sense of the material throughout the lesson. The teacher provided the new concepts to the students and posed many of the problems, and the students worked at integrating the knowledge into their understanding of acid-base reactions. The students freely asked questions about the new material and participated actively in solving the practice problems posed by the teacher. They also asked questions about how the new material related to topics previously studied, such as how normality is related to molarity. The teacher provided a few simple problems in these cases to show students the connections. It was clear that students understood the concept of equivalencies and that they were able to relate this new knowledge to other topics. The students were also able to master the proper technique for using a pipette, increasing their capacity to carry out investigations in chemistry.

Sample High Quality Lesson: Reform-Oriented Instruction

This high school biology lesson was in the middle of a unit on cells. In the previous lesson, students had conducted a membrane lab in which they placed either starch or sugar solution in dialysis tubing and then submerged the tubing in a beaker of water with indicator. The purpose of today's lesson was to begin to draw together ideas about molecule size and transport across cell membranes.

The lesson began with the teacher asking the students, in their lab groups, to predict what they expected to have happened with their lab (i.e., whether the starch and/or sugar would have diffused across the membrane) and to use the concept of particle size to explain why. After they had made a prediction, the groups examined their data and discussed whether their prediction was right or wrong. The teacher then led the entire class in a discussion about what had happened in the experiment. Students suggested hypotheses, and the class discussed methods for testing them. As needed, the teacher chimed in with suggestions (e.g., using test tape to measure sugar content), but his role was primarily providing lab techniques that would enable the students to test their ideas and prodding the groups to make sure they conducted enough tests to fully explain what had happened. This segment of the lesson worked extremely well, with the students in charge of their investigations and doing the majority of the intellectual work. The teacher kept to his role of facilitator, questioning students and giving them suggestions for lab tests.

The teacher skillfully guided the students as they finished making observations and analyzing the data, asking questions that pushed students to examine their results and to provide evidence for their conclusions. Examples of questions asked by the teacher are: "How could we test if there is still sugar in the reservoir?" "Why didn't (the iodine indicator) reach an equilibrium?" and "How do you know?"

The teacher also introduced new vocabulary to the class as appropriate. For example, as the students were trying to explain what had happened to the sugar in their experiment, the teacher interjected to the whole class "I hear you discussing, let me introduce a term: equilibrium." Thus, the teacher was able to ease new content into the discussion in the context of the investigation.

After the groups had finished all of their tests, the teacher gave them an assignment to write a story about a paramecium that lived in the local freshwater river who decided to go see his girlfriend who lived in the ocean. The groups were instructed to write about his trip and what he would experience. The teacher supplied them with a list of eight vocabulary words related to transport across a membrane that they had to use in the story. The groups were told that the teacher would call on one group member to read and explain their story to the class the next day, so they all needed to understand the concepts they included. The students spent the remainder of the class period working on their stories. This activity provided a good opportunity for the students to bring together what they knew about transport across a membrane and apply it to organisms living in their local river. It was a critical component of the lesson as it allowed the class to make sense of the lab results.

This lesson was an example of high-quality, reform-oriented science teaching. All of the students were engaged in meaningful investigation of important science content, and the teacher did a masterful job of guiding the class. Students were generating and debating hypotheses, and were given the tools they needed to test their ideas. Writing a story about a paramecium's travel from fresh to salt water provided a perfect opportunity for the students to make sense of the data and conclusions drawn from the lab investigation. The classroom culture was superb—students had clearly taken ownership of their learning, and the teacher pushed and challenged all students to engage with the content. It is highly likely that this lesson enhanced students' understanding of the concept of transport across a cell membrane, as well as their capacity to carry out their own inquiries.