Teacher professional development and classroom resources across the curriculum

Case Studies in Science Education

Support Materials

Case Studies in Science Education

Audrey, Year One — Grade 8

Teacher Profile

Name	Audrey
Experience	13 years
Grade & Subject(s)	Grade 8; science and social studies
Classroom	3 sections; 90 students total; 90% African-American and Hispanic
Demographics	Middle school in an inner city setting
Science Teaching	90 minute sessions on alternate days of the week
Curriculum	Developed by the teacher
Other	Third year teaching middle grades. Background is in social studies and elementary education

Contents

Module 1 - Introducing the Case

Audrey wants to empower her students to think and to speak for

themselves in all areas of learning, including science. Building a science curriculum and connecting science teaching and learning with students' lives challenge Audrey, whose background is social studies. Because the district-wide science curriculum is in transition, Audrey is left largely on her own to decide what to teach her students.

Early in the year, Audrey's students participate in activities at science center, which Audrey has set up in the classroom. Students work together, following directions for six activities that Audrey has found in science activity books. Audrey pushes her students to take their ideas and discoveries one step further, working all the time toward her goal of empowering her students, in this case, by trying to foster self confidence and enthusiasm, which Audrey believes will be requisites for high school science.

We see further evidence of this goal when Audrey's students explain their exhibits to visitors at the science fair. By explaining what they have learned, students gain the experience of speaking for themselves and explaining their understandings. Audrey searches for other ways to help her students believe that they can succeed.

Work Station Activity

Students work together at six science centers, conducting hands-on explorations of varied science topics. Participation at the six work stations spans one class session.

Discussion Questions

What do you observe to be Audrey's strategies for making connections between science and students' lives?

Where do you think a knowledge of science fits into the "real world" that confronts students today?

How would you develop a curriculum that includes the needs and goals of your students?

Module 2 - Trying New Ideas

Audrey seizes the opportunity for students to make connections between some of the big ideas in science with the school's current theme of African-Americans. Moving from single session activities, Audrey moves toward theme-based learning.

Groups of students look to historical accounts and identify some of the inventions of African Americans. Each group selects an inventor and then focuses on his or her invention. Audrey assigns each group to present a skit or demonstration that shows the group's understandings of the invention. Audrey sees this communication of what students have learned as another way to empower them with the belief that they, as African Americans, can make meaningful contributions to science.

Audrey senses a growing comfort with the give and take of learning science between herself and her students. This "teach me" approach can be used as a way for students to explain their scientific understandings to Audrey and to other students.

Inventor Research Project

Groups of students research an African American inventor and then give presentations of the importance of his or her invention to the full class. Within the presentations, students must identify the scientific discipline involved and the major scientific concepts and then demonstrate a basic understanding of one or more concepts.

Discussion Questions

Given Audrey's goals for her students, what do you consider to be the strengths of the African American inventions unit? The weaknesses?

When do you think strategies for building self esteem detract from

strategies for building a sound knowledge of science? When do these strategies support one another?

How would you develop a curriculum where you were as much of a science learner as your students?

Module 3 - Reflecting and Building on Change

Audrey embarks on a unit new to herself and her students by using a "teach me" approach. Students collect and bring to class newspaper articles and then discuss how they relate to the environment. Audrey's goal is to help her students understand and appreciate science in its global, or community, sense. After suggesting to students that they will again participate at science centers that she will set up, her students clamor to be the decision makers in the environmental topics that are to be explored and the manner in which their findings will be reported.

Audrey admits that the task of tracking this more unwieldy activity was monumental. To Audrey, this effort pales in comparison with the extent to which the students feel empowered to research and share with the community their understandings of such environmental topics as the ozone layer, acid rain, and energy. This empowerment is evidenced by the group presentations that exemplify the environmental issues and questions that framed the study.

In keeping with Audrey's sense that students need to be connected to the larger community, each group wraps up their presentations with an activity that students can do within their own community to address an environmental issue.

Environmental Studies Report

Students research and prepare reports on why a particular environmental issue is important to a community, how we as a community impact it, and

what the world will be like in the year 2000, if we as a community do nothing now to address the issue. Groups offer community service projects and submit written discussions of their findings.

Discussion Questions

How does the environment unit compare to Audrey's earlier use of science centers? To the African American inventors unit?

In your opinion, what are the advantages and disadvantages of a "teach me" approach to developing a science curriculum?

How would you build in opportunities for your students to apply their learning in science to personal, social, or environmental issues?

Case Studies in Science Education

Audrey, Year Two — Grade 7

Teacher Profile

Name	**Audrey**
Experience	**14 years**
Grade & Subject	**Grade 7 science**
Classroom	**Middle school in an inner city setting**
Demographics	**5 classes; 150 students, total; 90% African-American and Hispanic**
Science Teaching	**5 meetings per week**
Curriculum	**Developed by teacher**
Other	**First year teaching seventh-grade science**

Contents

Module 1 -- Introducing the Case

Audrey has polled her class and discovered that what students most want to learn about in science is the human body. Building on this motivational topic, Audrey develops a unit that explores the human muscular and skeletal, circulatory, and digestive systems. At the end of the unit, Audrey encourages her students to provide evidence of their understandings by explaining the reasons for their answers to questions. Convinced that students could do more to explain their reasoning, Audrey uses interactive questioning techniques to draw explanations from students.

At the heart of Audrey's science teaching and learning is her desire for students to feel good about themselves and, in turn, to feel confident that they can learn. One manifestation of this is her introduction of the Latin names for the skeletal system. Audrey hopes to connect activities that build students' self-esteem along with their reasoning skills as a way for them to become more confident critical thinkers.

Skeletal System Activity

After studying the human skeletal system, students construct drawings of the system on cardboard templates, then name each bone, using both common and Latin terms.

Discussion Questions

In the human body unit, what opportunities, if any, provide students with opportunites to think critically? What does "think critically" mean to you?

What does it mean to think critically in science?

From start to finish, how do you think opportunities for critical thinking can be built into a unit of study in science?

Module 2 -- Trying New Ideas

Audrey meets with Jeff Winokur, a science educator at Wheelock College. Together they discuss the four phases of one version of the learning cycle and how critical thinking can be integrated with these phases. Audrey will use this model with her class as a way of developing

students' critical thinking skills.

At the beginning of the physics unit on structures, Audrey elicits from her students what they already know about structures as a way of beginning Phase One, Getting Started. During a walk around the nearby community, Audrey engages in interactive questioning as a way of helping students connect with their prior understandings. In this phase, Audrey's invitation for students to think critically is not constrained by the experiences students have shared, but rather, is drawn from their own diverse backgrounds.

To launch the next phase, Exploring and Discovering, Audrey challenges students to build the tallest, strongest structure they can by using plastic straws and paper clips. Audrey sees her role as a keen observer of what is happening during this phase; she asks questions that derive from students' hands-on experiences to help students build and explain their understandings.

Structure Activity

Groups of students are challenged to build the tallest and strongest structure they can, using plastic straws and paper clips. Later, students test the strength of each structure by dropping coins into a paper cup suspended from the structure until it collapses.

Discussion Questions

What do you consider to be the strengths and weaknesses of Audrey's approach for engaging students in critical thinking during Phase One (Getting Started) of the structures unit? During Phase Two (Exploring and Discovering)?

What do you consider to be the essential aspects of the teacher's role in fostering critical thinking? Of the student's role?

Once students have had preliminary experiences within a unit of study, how do you think these experiences can be built upon to further critical thinking?

Module 3 -- Reflecting and Building on Change

The third phase of the model, Processing for Meaning, is implemented by means of a bridge-building project. First the whole class reviews some

of the physics terms and their meanings. By being asked to build the strongest bridges, students are called upon to make meaning of what they have learned from previous activities with structures and apply that meaning to construct another structure.

During the fourth phase, Elaborating Upon Ideas, students are engaged in building the tallest, strongest structures they can by using their own choice of household materials. Audrey helps students by guiding them through an organizational period wherein she elicits students' ideas about materials and reviews what students already know about what makes structures tall and strong. Upon completion of the project, Audrey is pleased with the extent to which students have taken previous learning experiences, reflected upon them, and applied them to the project at hand.

Free Form Structure Project

Groups of students bring to class materials such as cardboard, craft sticks, and connecting blocks, which are used for constructing the tallest, strongest structure possible. After a period where groups of students work independently to build their structures, they explain the structure design to the full class and test the strength of the structure by adding weight.

Discussion Questions

What do you consider to be the strengths and weaknesses of Audrey's approach to engaging students in critical thinking during Phase Three, Processing for Meaning? During Phase Four, Elaborating Upon Ideas?

In your experience, what are the greatest challenges in engaging students in critical thinking as a part of science? How might teachers overcome

these challenges?

Which aspects of this learning cycle model do you find most useful with regard to fostering critical thinking? Which aspects are least useful? Why?

Case Studies in Science Education

Donna — Grade 5

Teacher Profile

Name	Donna
Experience	22 Years
Grade & Subject(s)	Grade 5; all subjects
Classroom	25% Native American; 25% Hispanic
Demographics	Elementary school in a rural district
Science Teaching	5 hours per week
Curriculum	Teachers are given the freedom to make choices in an integrated curriculum.

Contents

Module 1 - Introducing the Case

Donna wants her students' heritage to be part of the science teaching and learning that takes place in her classroom. As teacher of a class that draws many students from many backgrounds, Donna looks for ways to incorporate their rich cultural heritage with her teaching of science. This year, because she has several Native American students in her class, Donna has decided to focus on the views held by many native peoples about nature as her class studies the local environment.

Thom Alcoze from Northern Arizona University discusses how one way of integrating Native American ideas with other science activities is by studying their myths and stories about nature. Donna decides to integrate storytelling by asking students to study and retell Native American myths as part of a unit on native plants and animals. Donna wants her students to understand that the observations expressed in the myths and stories often have scientific understandings at their foundation. By developing a deeper understanding of their own ancestry and cultural heritage, Donna believes that all her students will be better able to integrate the science they are learning with their backgrounds.

Storytelling Activity

As the conclusion to a study of native plants and animals, students share myths and stories about a familiar animal, the coyote.

Discussion Questions

What are your thoughts about the importance of bringing ideas from the different cultural backgrounds of your students into science teaching and learning?

How do you react to the idea that "only mainstream America has science?" If this idea were actually reflected in science teaching and learning, what might the impact be on the science understandings that minority students develop?

Using storytelling about nature to bring ideas from different cultures into science teaching and learning, how could you help students develop sound scientific ideas about the natural world? What are some other ways you might integrate ideas from different cultures to foster science learning?

Module 2 - Trying New Ideas

As a way of continuing to work toward bringing ideas from different cultures into science teaching and learning, Donna and her class investigate regional archaeology, while focusing on the Native Americans who once lived in the area.

Donna uses students' stories and essays about these early peoples as a starting point. The class then takes field trips to nearby archaeological dig sites, one of which is preserved while the other is active. Students view the sites and artifacts found there as a way of finding answers to the questions that students have. Guides at each site are available to help students explore the site and also to provide interpretations of the findings at each site.

Students return to their classroom to discuss what they learned and use it to answer questions. Donna continues to work with her students, helping them to respect their past and to assume responsibility for the future.

Archaeology Study

Students write stories that reveal their ideas why people living in the area centuries ago may have abandoned their settlements. Later, the class takes two field trips to a nearby archaeological site. The first is to a preserved archaeological site, where the park ranger leads students on a tour to help them consider the conditions under which the native inhabitants lived. The second field trip is to an active archaeological site where the public, with instruction and supervision, can help excavate. Using these experiences, students begin to answer some of their own questions.

Discussion Questions

How would you critique the archaeological study as a way of introducing students to the scientific ideas of a culture different from their own?

In your opinion, what are the greatest benefits of bringing the ideas of

past civilizations into the study of modern science? What are the greatest challenges?

How would you integrate an ethical dimension into the study of science?

Module 3 - Reflecting and Building on Change

Donna and her students continue to use archaeology to focus on the ideas of different cultures in a scientific context. She begins by asking students to list elements that are common to every culture, such as food and shelter.

Using this list, students make a chart identifying artifacts that represent these elements through several generations: the students' own, their parents', their grandparents' and those of more distant ancestors. After querying family members, groups of students make shoe box middens by collecting household items that represent cultural artifacts of a combined "clan," both past and present. Middens are exchanged between groups, who "excavate" the shoebox middens to determine the "past" as evidenced by the artifacts of the clan.

As a way of furthering students' understanding of the implications of decisions for which scientific knowledge has a bearing, students participate in role-play activities. Students take on the roles of different interested parties, including non-human species and inanimate parts of the environment, when a piece of land with Native American ruins located on it is made available to developers. Donna is hopeful that her students are becoming citizens who will care about others and value ideas from other cultures.

Middens Activity

Students complete a chart identifying elements, such as food, shelter, medicine, and transportation, that are common requisites of different cultures. Groups then work together to construct shoe box middens (collection of items that would be found in a refuse heap), which are

taken to be representative of a "clan." Groups then anonymously exchange middens and excavate, map, and interpret findings. Groups share their findings with the full class and offer conjectures about the habits of the clan.

Discussion Questions

Using the middens activity as an exmple, how would you uncover, value, and use ideas from different students' cultures in your classroom in another content area?

In your opinion, what is the appropriate balance between helping students build scientific knowledge and helping them explore the ethical use of science throughout their lives?

What is your position on including, as a part of science teaching and learning, an examination of the values and ideas about the natural world that students bring with them from their cultures?

Case Studies in Science Education

Dotty — Grade 7

Teacher Profile

Name	Dotty
Experience	23 years
Grade & Subject(s)	Grade 6 and several Grade 7 students; all subjects
Classroom	Multiethnic
Demographics	Grade 6 and several Grade 7 students; all subjects
Science Teaching	5 hours per week
Curriculum	Derives this year from the Tennessee Valley Project; previously built around objectives for state standardized test

Contents

Module 1 - Introducing the Case

As part of the Tennessee Valley Project, which was designed and funded to improve science education in eight rural districts, Dotty begins the year with what will become an in-depth unit on water. Using

computer technology provided to Dotty's school through a previous grant, the Project has made it possible for Dotty and her students to go on-line and use telecommunications as a resource.

Along with her fellow Project members, who also have obtained the necessary computer technology, Dotty's plans are to implement a Science-Technology-Society (STS) approach to teaching and learning science. The goals of integrating technology, developing partnerships with willing educational resources, and addressing a state framework and the national standards are woven throughout the Project.

Teachers decide that students will have a great deal of control over the direction and depth of their studies, which is a different approach for Dotty. Dotty wonders whether this non-traditional approach can be implemented successfully.

Tennessee Valley Project

Teachers from eight rural districts participate in a summer workshop as preparation for a year-long science curriculum that will use telecommunications within a Science-Technology-Society (STS) approach to teaching and learning science. Participants will teach science that focuses on water during the fall and energy in the spring. Internet access is provided, as well as some initial contacts for establishing partnerships with educational resources.

Discussion Questions

What issues does Dotty's situation and her participation in the Tennessee Valley Project raise for you?

What do you consider to be the key elements in a curriculum that aims to develop an understanding of the relationships among science, technology, and society (STS)?

How would you integrate telecommunications into a curriculum, using an STS approach?

Module 2 - Trying New Ideas

Students begin their water study by bringing to class and then testing water from local water supplies. Students decide to send requests for water samples by means of the Internet. As a goal, students will collect samples from all 50 states. Students mark a map of the United States as a way of tracking where the samples originate.

Dotty interprets Project goals for STS to mean that students use an inquiry-based approach to investigate water in the context of the issues inherent to the region. A field trip to an environmental education center with a class from an adjacent district enables students to gather additional data for their investigation. As the water study nears completion, representatives from each participating school meet at the Tennessee Aquarium, a partner in the project, to share observations and results.

Dotty feels more connected with other teachers now that she can get on-line and share ideas and dilemmas. Her students have recognized the benefits of connecting with their peers from other schools, as well as the educational resources that they found on the Internet.

Water Study

Students gather water samples from many sources throughout the United States. As a geography connection, students use yarn and a map to identify the sources of their samples. Using water testing supplies that were donated by a resource identified through the Internet, students test for pH and dissolved oxygen. Students also explore a nearby branch of the Tennessee River to determine the characteristics of the living and non-living environments there. As a culminating activity, representatives from each participating 6th grade attend Link-Up Day at the Tennessee Aquarium, where ideas and understandings are shared and built upon. Dotty wonders now about assessment. Can she expect students to represent what they know by "bubbling in" answers on a multiple choice test after all the hands-on active, inquiry-based learning that has taken place?

Discussion Questions

Which aspects of Dotty's use of telecommunications in the water study do

you consider to be the most useful in science teaching and learning? Least useful? Why?

What reasons can you give both for and against letting students "learn it [science] the way they want to"?

What strategies would you use for assessment if your goals were to align with the type of approach to science teaching and learning that Dotty takes with the water study?

Module 3 - Reflecting and Building on Change

Knowing that the Project specified that the last half of the school year be centered around energy and recognizing that her students feel such a degree of ownership of the water project that they are reluctant to let it go, Dotty and her class decide to investigate hydroelectricity. The regional connection is apparent in view of the region's reliance on dams and hydroelectric power plants on the Tennessee River.

Once again taking the lead in the direction of their studies, groups of students generate questions about hydroelectricity that connect closely with what students learned in the water study. Then they set out to find answers. As part of their search for answers, Dotty's class visits the Energy Connection, an educational resource located at the dam and power plant near the school. Students pose their questions to the guide, who shares his ideas with the class. Dotty feels that traditional forms of assessment do not align with the more progressive approach that she and her students have taken this year. Together, Dotty and her students decide upon a method of assessment that they think will best represent what students have learned. The result is a multi-faceted assessment that includes model building, oral presentations, written work, peer evaluations, and self-evaluations.

Hydroelectricity Study

Groups of students formulate their own questions about hydroelectricity. Using the Internet, local educational programs, and other resources, students set out to answer their own questions.

Discussion Questions

Based on what you observed of the hydroelectricity study, how would you critique this second project for the elements of science, technology, and society, and their relationships?

What position do you take with regard to providing students with opportunities to be assessed in both more traditional and more progressive ways?

How would you go about including your students in decisions about how science understandings are assessed?

Case Studies in Science Education

Elsa — K

Teacher Profile

Name	Elsa
Experience	15 years
Grade & Subject(s)	Two half-day kindergarten classes; all subjects
Classroom	Bilingual classroom
Demographics	Elementary school in an urban district
Science Teaching	2 days/week for 30 minutes
Curriculum	Specified by district

Contents

Module 1 - Introducing the Case

Elsa believes that for many children, what happens in kindergarten affects students' feelings about and learning in school for the rest of their lives. She is beginning to ask questions of herself and rethink her approach to teaching science. Knowing that her students become engaged whenever they are using their senses to explore objects and phenomena,

Elsa wants to build upon her students' natural inclination to learn by making their own discoveries. She hopes to extend this type of learning to meaningful expressions of students' understandings.

Seasons Study

To initiate discussion of seasonal characteristics, Elsa reads aloud a picture book. Students are then asked to verbalize what they know about seasons. Finally, students are given paper divided into four sections and asked to draw a picture that represents each season.

Discussion Questions

Given Elsa's interest in having students "participate more" during science activities, what would you describe as the strengths and weaknesses of the seasons study?

What role do you think "free exploration" of objects and phenomena should play in helping students develop basic scientific understandings?

How would you design activities so that students are likely to make scientifically accurate "discoveries?"

Module 2 - Trying New Ideas

Jeff Winokur, an early childhood science educator at Wheelock College, has observed in his teaching practice that young students cherish playing with materials and that this fascination can be put to use to help them make scientific discoveries. During students' discovery of magnets, Elsa

takes a "guided discovery" approach by getting students to work with a partner as she circulates through the classroom, helping them move toward making specific discoveries.

After working in pairs, where materials are shared, each student completes a worksheet that reflects his or her findings about materials through which a magnetic force can travel. Later, the class reviews the worksheets together. Elsa believes that when students take their worksheets home, students' understandings are again reinforced when shared with family members.

Magnet Study

After a period where students find out what magnets will and will not pick up, student pairs work together in a guided discovery activity to determine whether magnetic force can travel through various substances such as water, paper, wood, and cloth. Students record their discoveries on worksheets and discuss their findings with the entire class.

Discussion Questions

In comparing the magnet study to the seasons study, what do you consider to be the most important changes with regard to getting students to be more actively engaged?

What meaning does the "discovery method" have for you? How would you contrast "free exploration" with "guided discovery?"

What would you do to help students reach scientific conclusions and represent their learning after a "discovery" activity?

Module 3 - Reflecting and Building on Change

As the year progresses, Elsa is convinced that science has become her students' favorite activity period. As part of her final science unit, Elsa invites her students to mix food coloring in water to find out what happens. This time, pairs of students each have their own materials but are encouraged to share their results.

One of Elsa's goals is that students notice consistent results from mixing certain colors. Another goal is that students develop ways of expressing their findings. Overall, however, Elsa recognizes that this activity allows many different outcomes as students pose their own questions and find their own answers by mixing colors.

Elsa is learning that with discovery activities, even though a scientific concept is not necessarily being discovered, her students are making their own discoveries and beginning to build new knowledge. Having never seen this before, Elsa is elated.

Mixing Colors Activities

Students mix food coloring in water to discover what happens when different colors are combined. Discoveries are shared between partners and with Elsa. Later, students use colored cellophane as overlays to see what other changes in color can result. Both activities are designed to reflect a more "open discovery" approach.

Discussion Questions

How would you compare the purposes and the outcomes of the mixing colors activity with the magnet study?

In your opinion, what is the appropriate balance between free exploration, guided discovery, and open discovery in elementary science? In later grades?

Focusing on a specific science concept appropriate in your teaching situation, how might you integrate more teacher-structured with less teacher-structured activities as a means of fostering scientific understandings?

Case Studies in Science Education

Erien, Year One — Grade 5

Teacher Profile

Name	Erien
Experience	Student teacher
Grade & Subject(s)	Grade 5 science, mathematics, and social studies
Classroom	30 students
Demographics	K-8 elementary/middle school in an industrial suburb
Science Teaching	50 minutes; 5 days per week
Curriculum	District specified
Other	Undergraduate degree in environmental studies Will hold master's degree in education with elementary and middle school certification

Contents

Module 1 - Introducing the Case

Erien is focusing her attention on generating and responding to

productive questions in her classroom. As part of her five-week middle school practicum, Erien and her students explore the wetlands that surround the school building, gathering data for a soil profile activity. While students are engaged in the activity, Erien circulates among groups outdoors, trying to pose questions that help students focus on the observations they need to make. Erien wants the discussions that take place to be student-centered, yet she wonders how that can be accomplished in such a way that all questions are addressed, effective classroom management is maintained, and specific learning goals are met.

Soil Core Activity

Groups of students investigate the wetlands that surround the school building. Each group digs a hole at a different site and records observations of soil texture, moisture, particle size, living things, and other features at five specified depths. Students collect a soil sample and return to the classroom to process their results.

Discussion Questions

How would you describe Erien's approach to science teaching and learning?

Which aspects of the soil profile activity are likely to contribute to meaningful class discussion?

What discussion management strategies do you think support a student-centered learning environment?

Module 2 - Trying New Ideas

After meeting with Tom Dana of Pennsylvania State University, Erien decides to try elaborating upon her discussion management strategies. Erien discovers that the soil profile activity has provided students with a common science experience that can contribute to a discussion that includes and is meaningful to all students.

Questions that focus on learning goals are asked of groups by Erien. However, the bulk of the questions and answers that are exchanged occurs between students. Erien observes that students can play a part in moderating discussion and discovers that their questions offer avenues for students to compare their findings and support or refute one another's ideas.

Erien shares with us her strategy of taking a poll, or vote, whenever she senses that attention is wandering or particular students are not being recognized. This vote-taking helps bring the class together and encourages involvement by all students. Erien hopes to apply her newfound strategies to other discussion situations.

Soil Profile Activity

Groups of students transform and interpret their wetlands data by preparing posters showing soil profiles, which are presented by groups to the whole class. Discussion questions are posed by class members to the presenting group.

Discussion Questions

In your opinion, what elements of Erien's approach to discussion seem to be most successful? Least successful?

What do you think are the biggest challenges that discussions pose for classroom management?

How do you think teachers can structure student-centered discussions to balance the need to meet learning goals with the need to foster student interaction?

Module 3 - Reflecting and Building on Change

Erien still finds herself trying to balance her content goals with her needs for classroom management and students' needs for individual recognition of ideas.

Having found success in relying on students to generate and answer one another's questions, Erien embarks with her class on a one-day activity. As part of a mock town meeting where townspeople are considering the construction of a retirement housing facility on or near a wetlands, students assume the roles of environmental experts, builders, concerned neighbors, even wildlife aficionados. As part of the role-playing, "town meeting participants" query "panel members," who have prepared diagrams and line drawings showing design and site plans as blueprints would.

By embedding science in such real-life scenarios, Erien shares with her students the valuable role that science understandings can play in meaningful decision making.

Town Meeting Activity

As the culminating activity in the wetlands unit, students apply their knowledge in a role-play activity that mimics a town meeting. Students become experts, business people, townspeople, and others who are charged with making an environmental decision involving the placement of a structure on or near wetlands.

Discussion Questions

What comparisons can you make between Erien's first and second class discussions?

What do you think are some of the necessary conditions for a meaningful class discussion in science?

How would you incorporate class discussion into other areas of your science curriculum?

Case Studies in Science Education

Erien, Year Two — Grade 7

Teacher Profile

Name	Erien
Experience	First year
Grade & Subject(s)	Grade 7 science and language arts
Classroom	Two classes of 24 students
Demographics	K-8 elementary/middle school in an industrial suburb
Science Teaching	50 minutes, 5 days per week
Curriculum	Specified by district

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Module 1 - Introducing the Case

In their study of the human body, Erien's students dissect a lamb kidney and compare it with a human kidney as a way of furthering their understanding of the structure and function of the excretory system. When exploring the respiratory system, her students are challenged to prepare a

skit that demonstrates their understanding of how the system functions. In addition to providing meaningful, hands-on learning experiences in science, Erien has set a goal for herself of enabling her students to become creative and critical thinkers to further their scientific understandings. Her challenge is to achieve this goal by means of a language arts connection.

Excretory And Respiratory Systems Study

As part of their study of the excretory system, students color and label detailed diagrams and build simple models. Next, students dissect a lamb kidney to compare with a human kidney. After studying the respiratory system, student groups are issued index cards, each containing a different challenge requiring students to prepare and present a skit as a way of making meaning of previous work.

Discussion Questions

How would you describe of Erien's use of reading, writing, and speaking as a part of science activities?

What place do you think language arts has in science teaching and learning?

If you were to concentrate on using language arts to develop critical and creative thinking in science, what would you do? Why?

Module 2 - Trying New Ideas

Erien meets with Sue Mattson, a science educator at the Smithsonian Institution. Together, they explore ways in which writing can be used to integrate language arts into science and to help students make meaning of what they learn.

As a component of their study of the immune system, Erien's students write before and after an activity designed to educate students about infectious diseases. Encouraging students to write before an activity is one way that they articulate their prior understandings and uncover their ideas. This becomes a valuable resource when students reflect on the outcome of a science activity in relation to their earlier understandings.

Immune System Study

After participating in an activity simulating the spread of infectious diseases, students perform a "bacterial handshake experiment." Standing in four lines, the first person in each line touches a gloved hand to a solution of harmless but brightly colored bacteria and handshakes ensue down the line. Each line is then assigned a different action: no soap or water, water only, regular soap, and anti-bacterial soap. Students then swipe their fingertips on petri plates containing sterile media. Students form hypotheses, record and interpret results, and construct conclusions after observing the growth of bacterial colonies on plates over time.

Discussion Questions

How would you critique Erien's use of writing as a way of helping students make sense of the "bacterial handshake" activity?

What do you consider to be the pros and cons of using writing as a way of helping students learn science?

How would you include writing as an integral part of a science study to help students "think like scientists?"

Module 3 - Reflecting and Building on Change

At the end of the year Erien takes advantage of the wetlands surrounding the school to introduce students to ecology. After students have had time to explore the area and record their observations, students generate questions and record them in their journals, to form the basis of their own studies outdoors.

Previously dissatisfied with the results of leaving journal entries up to the discretion of her students, Erien prompts students' writing in their journals throughout the various phases of ecology study. One way Erien does this is by providing students with sets of questions to help frame students' thinking and subsequent writing. This results in the more extensive use of a journal, not only as a place to record data, but also as a place for students to learn how to think critically about the results of their experiments and how to use creativity in applying what students have learned to real-world situations, and/or future science studies.

Ecology Project

Students explore the wetlands surrounding their school before generating questions which form the basis of a research project. Students design their studies, collect and interpret data, and present their findings to the class about topics such as the kinds of insects found in bark, the effects of temperature change, and the comparative rate of decomposition of different items.

Discussion Questions

Which aspects of Erien's use of journals in the ecology study do you find most useful? Least useful? Why?

In your opinion, what are the distinctions between critical and creative thinking in science? What are the similarities?

What are some other ways you could use language arts to help develop critical and creative thinking skills in science?

Case Studies in Science Education

Greg — Grade 6

Teacher Profile

Name	Greg
Experience	Student teacher in Master of Education program
Grade & Subject(s)	Grade 6, all subjects
Classroom	60% Hispanic; 40% White
Demographics	Urban K-8 school
Science Teaching	5 hours per week
Curriculum	Specified by district
Other	Participant in an accelerated program for teachers in urban and inner-city schools

Contents

Module 1 - Introducing the Case

Greg's practicum occurs in a school building that has recently been constructed and outfitted with state-of-the-art computer and telecommunications technology. The science curriculum is built around a videodisc science program that has been adopted by the school district. While he finds the content valuable, he sees the teaching mode as very limiting. Greg searches for ways to bring what he has heard referred to as a hands-on, minds-on dimension to his science classes. His goal is to incorporate more active experiences involving electricity in his upcoming science lessons.

Current Electricity Lesson

Greg launches an electricity unit with his class by viewing a lesson from a video disc. The objectives for learning include what current electricity is, what composes an electric circuit, and what makes good insulators and conductors. When he feels it is appropriate, Greg stops the player to ask questions of his students and to encourage discussion of the ideas presented on the video disc.

Discussion Questions

What issues about science teaching and learning does Greg's experience as a student teacher raise for you?

In what ways can you identify with the difficulties of bringing educational theory into real classroom practice?

What do you consider to be the critical components of a "hands-on, minds-on" science activity? "Teacher-centered" vs. "student-centered?"

Module 2 - Trying New Ideas

Greg meets with Sue Mattson of the Smithsonian Institution. Together they discuss ways to integrate individual, group, and full class strategies so that each student has an opportunity to learn with understanding. They also discuss the importance of connecting hands-on and minds-on work by having students not only use materials as part of an activity, but also by having them reflect upon and represent their learning in some way.

Greg opts to teach his next science lesson in the school's lab, where group seating arrangements exist. He believes that this setting can help him move toward a more student-centered learning environment.

On one day, groups of students are guided through the construction of series and parallel circuits. They use batteries, wires and bulbs to make their construction. The next day, Greg tries to assess students' understanding by having these same groups build "circuit boards," which involves students in making connections among recently introduced terms. He looks toward increasing attention for individual learners.

Current Electricity Lab Activities

In a lab setting, groups of students first construct series and parallel circuits, using batteries, wires and bulbs. Later, students work together to build circuit boards. Groups develop a matching activity wherein connected concept pairs are written on the front of the circuit board. Next, using tacks and wire on the rear of the board, students make a physical connection between concepts. Groups challenge one another to make the correct connections between concepts and use available components to complete a circuit that lights a bulb.

Discussion Questions

In your opinion, what evidence exists that Greg has moved toward a more "hands-on, minds-on" approach to science teaching and learning? Toward a more student-centered?

What rationale can you give for using group work as a way of increasing the possibilities for individual learning?

What are some additional ways to provide opportunities for each student to learn with understanding?

Module 3 - Reflecting and Building on Change

Greg hopes to determine how previous activities have contributed to students' present understandings of concepts involving electricity. He

changes his focus from primarily full class and group work to include more individual work. But first, each student is given the time and space in which to make sense of prior hands-on activities. Next, students work together, sharing one another's ideas as they work toward group consensus. Greg looks toward a teaching career in which he continues to learn ways to create hands-on, minds-on, student-centered learning environmenst in science.

Battery And Bulb Activity

Each student is asked to think about, write about, and draw how two wires and a battery can be used to light a bulb. Next, groups of students discuss one another's ideas and develop written descriptions and drawings showing how the group thinks these materials can be used to light a bulb. Groups then gather the materials and follow their own directions for lighting the bulb. Finally, each group, followed by each student, modifies the original ideas. What do you consider to the be the most important changes Greg has made to support the individual learner?

Discussion Questions

Under what circumstances do you think a hands-on, minds-on, student-centered learning environment is fostered by full-class activities? Small group activities? Individual activities?

How would you integrate different modes of classroom organization to promote individual learning?

Case Studies in Science Education

Ingrid — Grade 1

Teacher Profile

Name	Ingrid
Experience	Two years
Grade & Subject(s)	Grade 1; all subjects
Classroom	21 students
Demographics	Suburban elementary school
Science Teaching	50 minutes, twice per week
Curriculum	Life, earth, physical science; district specified
Other	Child psychology major

Contents

Module 1 - Introducing the Case

The issue that Ingrid shares with us involves how to use students' ideas to frame her teaching. She would like to build on each student's prior knowledge, combined with questions students have, to help them

construct scientifically accurate ideas. As part of a unit on air, water, and weather, students are exploring states of matter. When students begin exploring water, Ingrid uses methods such as full-class brainstorming and inventive spelling in journals to help students express and share what they already know and what they want to learn about water. At present, Ingrid accepts all questions and hopes to use future activities to help answer these questions. Ingrid wonders how she can attend to the diversity of ideas and questions students have without losing focus on the core concepts about water that are part of the goals for this unit.

Balloon Activity

Ingrid's students explore the properties of solids, liquids, and gases by using balloons containing frozen water, water in its liquid state, or air. Pairs of students make observations and record their ideas on a lab sheet. During the class discussion that follows, students share their conclusions. Ingrid continues trying to help her students understand that air takes up space by blowing into a balloon.

Discussion Questions

How would you describe Ingrid's approach to managing students' ideas in science?

Even after well-planned activities, why do you think students retain scientifically inaccurate ideas?

How might teachers help students work with their prior knowledge to construct scientifically accurate ideas?

Module 2 - Trying New Ideas

Ingrid expresses to Rick Duschl of Vanderbilt University her concerns

about full-class discussions where students' ideas and questions, while useful as starting points, may not be easily incorporated into activities focusing on key concepts. Rick suggests that Ingrid start discussions by using demonstrations as a way to help students focus their thinking and connect their ideas with a scientific concept. Ingrid demonstrates by using a tuning fork to introduce the concept of vibration. She then uses a ruler to demonstrate the relationship between the speed of vibration and pitch. When all students are given the opportunity to observe the same event, students express varying ideas and predictions. Ingrid uses these ideas and predictions as the basis for building consensus, with a view toward students' understanding that scientific ideas are grounded in evidence. To follow up on the demonstrations, partners stretch rubber bands on geoboards, and then pluck the rubber bands. As students participate in this activity, they are guided to discover more about the relationship between the tension of a rubber band and pitch. Using invented spelling and drawing, students process their experiences by recording their ideas and observations. Ingrid uses this student work as a springboard for dialogue with students, both written and verbal.

Sound Activities

As a way for students to learn more about sound, Ingrid first engages her students in discovering how parts of their bodies vibrate when sound is produced. To help students understand that vibration and sound are related, Ingrid demonstrates the sounds made by a tuning fork. She then uses different lengths of rulers plunked on a desktop to encourage students to consider the relationship between speed of vibration and pitch. Students explore sound with one another by plucking stretched rubber bands on their geoboards.

Discussion Questions

What impact do you think the demonstrations had on students' ability to make sense of difficult ideas involving sound?

What are the tradeoffs between activities focused on teachers' objectives and those allowing students to explore their own ideas?

How might teachers use the outcome of an activity, such as a demonstration or guided exploration, as a way of continuing to focus on specific goals for science learning?

Module 3 - Reflecting and Building on Change

Ingrid reviews students' journals and identifies three of the most common ideas that also can be linked to goals for student learning. After reviewing what students believe about sound, she challenges pairs of students to select one of the three ideas to test. As teams test these ideas by using geoboards and rubber bands, Ingrid observes and asks probing questions as a way of focusing students' investigations. Later, Ingrid revisits the three ideas to help students build consensus about the results of their experiments. As a means of assessing what students have learned about sound, students construct sets of drums and explain how they made the drum sounds vary, based on the science that students have learned. Ingrid shares with us her evidence that even primary grade students can connect ideas, formulate questions, think critically, make observations and predictions, and then test them and begin to make generalizations based on evidence.

Drum Activity

As a culminating activity for a unit on sound, Ingrid challenges students to build sets of drums that produce different pitches.

Discussion Questions

How would you describe Ingrid's approach to assessing students' ideas at the conclusion of the sound unit?

How would you interpret a situation where, at the culmination of a unit, consensus among students is reached regarding a difficult idea in science? Where consensus is not reached?

What issues did Ingrid's case raise for you about science teaching and

learning in early childhood?

Case Studies in Science Education

Jean — Grade 3

Teacher Profile

Name	Jean
Experience	19 years
Grade & Subject(s)	Grade 3; all subjects
Classroom	22 students; 15% special needs; 10% ESL
Demographics	Suburban elementary school
Science Teaching	Three times per week, approximately 120 minutes total
Curriculum	District specified
Other	Master's degree in elementary education; Teaches in an "open" school

Contents

Module 1 - Introducing the Case

The issue that Jean shares with us involves multisensory approaches to teaching and learning science. Jean has a diverse group of students, which

makes her more sensitive to the need for providing learning experiences and for assessing understandings in a variety of modalities, including visual, auditory, and kinesthetic. For example, Jean believes that there should be pictorial and other print materials for visual learners to access, just as kinesthetic learners should be provided with hands-on investigations and opportunities to "act out" ideas. Jean hopes that multisensory approaches to her science lessons enable all students to learn and encourages them to recognize and develop other ways of learning.

States of Matter Activities

By working with water in its different states, students explore the properties of solids, liquids, and gases, and the relationships among them.

Discussion Questions

How would you describe student diversity in Jean's classroom? In any classroom?

What are the implications of this diversity for science teaching and learning?

How would you design science activities so that the needs of diverse learners are taken into account?

Module 2 - Trying New Ideas

Jean finds that careful organization and planning ahead of time are essential if she is to provide multisensory approaches to science teaching and learning. During the mystery powder activity, carefully matched pairs of students understand that the success of cooperative work depends upon each member's active participation and understandings. While collecting, recording, interpreting data, and then communicating findings, students

are given the opportunity to use all of their senses to identify mystery powders. Jean notices that group members have productive discussions about characteristics of substances that often result in the process of negotiating meaning. Full-class discussion provides another opportunity for students to talk about their results. As with other activities, students' results are posted and made available for the class to see and use in future investigations.

Mystery Powder Activity

As the culminating activity in an extended unit, students rely on their prior knowledge from testing known powders to help them identify an unknown mixture of these powders by using indicators, making comparisons, and other methods

Discussion Questions

In your opinion, what features of the mystery powder activity support the goal of meeting diverse learners' needs? What features might hinder this goal?

How does Jean's approach to science teaching and learning compare to more traditional approaches?

How might a teacher design assessment activities that align with her goals for addressing student diversity?

Module 3 - Reflecting and Building on Change

At the end of the amphibians unit, Jean offers multisensory assessments that enable each student to show what he or she understands about the life cycle and characteristics of a frog. As the culminating activity, Jean and her students take a field trip to a nature reserve. Besides looking for and

identifying specimens of amphibians, students show their understandings in other ways. Some draw pictures. Others write words. Jean considers the field work as an assessment of what students understand and remember from their classroom investigations.

Amphibians Assessment Activities

With the frog's life cycle as the focus of the unit, students explore the stages of development from egg to adult frog. They demonstrate their understandings by making clay models of the stages of tadpole development. And additionally, students are offered a choice of writing or drawing pictures to show what each student knows. A field trip offers the opportunity for students to connect class work with the real world and to offer evidence of their learning.

Discussion Questions

In your opinion, what features of the mystery powder activity support the goal of meeting diverse learners' needs? What features might hinder this goal?

How does Jean's approach to science teaching and learning compare to more traditional approaches?

How might a teacher design assessment activities that align with her goals for addressing student diversity?

Case Studies in Science Education

Jeff — Grade 6

Teacher Profile

Name	Jeff
Experience	Student teacher; Cooperating teacher, Bernie
Grade & Subject(s)	Grade 6; science and mathematics
Classroom	2 classes; 55 students total; multiethnic
Demographics	Middle school in a suburban town
Science Teaching	50 minutes, 5 days per week
Curriculum	Specified by district
Other	Holds undergraduate degree in business. Will hold master's degree in education with elementary and middle grades certification

Contents

Module 1 - Introducing the Case

Jeff is two weeks into a six-week middle grades practicum. Bernie, Jeff's

cooperating teacher, has told Jeff that, as student teacher, he is free to try new things, recognizing that some may work and others may not. Additionally, Jeff met with Tom Dana of Pennsylvania State University before beginning his practicum. Jeff and Tom discussed problem-centered learning, since that is the approach Jeff has decided to use in teaching his ecology unit. Jeff tells us that he is planning his ecology unit as he goes, in an attempt to allow students to identify for themselves an ecological problem that needs to be solved. As a means of working toward this goal, groups develop concept maps, using the broad topic of ecology broken down into five subtopics and their related terms.

Bernie and Jeff discuss what he learned from the students' concept maps. Jeff knows now what students prior understandings are. But he still seeks a method for identifying a problem that can become the focus of his problem-centered teaching and learning.

Ecology Concept Map Activity

Students work together, making concept maps as a way of showing what they know about ecology and uncovering those topics that each student may want to explore in more depth. Ecology subtopics shown in the concept maps are food webs, community interactions, and environmental problems. Groups present their concept maps to the whole class.

Discussion Questions

What do you think the concept map activity reveals about Jeff's approach to problem-centered learning?

In your opinion, what are some of the characteristics of problems appropriate for engaging students?

How would you go about deriving appropriate problems for student investigation?

Module 2 - Trying New Ideas

Jeff decides to approach problem-centered learning by posing a problem whereby students learn in the process of solving that problem. After generating a list of environmental problems that humans face, groups of students choose a problem to investigate. Jeff poses three questions to help students structure their investigation. Next, students conduct research and explore the many aspects of the chosen problems. Finally, students explore the phenomenon in terms of its being a problem within their community.

In addition to library searches and multimedia research, some students decide to learn more about the problems they chose by doing simple experiments, which later become the bases for classroom presentations. One group, for example, is engaged in"making" acid rain as the class observes. Students pose questions to one another, sharing their understandings and articulating their answers to the original questions.

Ecological Research Project

As a means of investigating ecological problems and then proposing solutions, groups of students conduct their own research. To demonstrate what they know about their ecological problems, students give presentations and demonstrations to the whole class and then answer questions posed by classmates.

Discussion Questions

What processes did Jeff's students use to explore, enrich, and explain their understandings of specific ecological problems?

What do you think is the appropriate relationship between reading about science and "doing science" in understanding and proposing solutions to problems?

How might a teacher provide students with opportunities to connect problem-centered learning in the classroom with the"real world?"

Module 3 - Reflecting and Building on Change

As a culminating activity to the study of ecology and the environment,

Jeff and his students embark on a field trip to a nearby wildlife preserve located on the Atlantic coast. There, professional environmental educators guide Jeff and groups of students on a field study of the area's various habitats.

Jeff considers himself as much of a curious observer as his students. He coordinates what has been explored in his class with what is being presented by the guides. This encourages students to bring their knowledge from previous projects to this new experience. By asking questions and proposing answers, students transform their classroom ecological understandings to real-world experiences and begin to see how science connects their own lives with the world around them.

Ecology Field Trip

As a culminating activity, students participate in a guided exploration at a coastal ecosystem, which is different from their community.

Discussion Questions

What role do you think the field trip played in the unit on ecology?

How can a teacher know if his or her approach to problem-centered learning has been successful?

What rule of thumb would you use to design a unit based on a problem-centered approach to science teaching and learning?

Case Studies in Science Education

Jennie — K

Teacher Profile

Name	Jennie
Experience	20 years
Grade & Subject(s)	Kindergarten; all subjects
Classroom	70% white; 30% non-white
Demographics	Elementary school in an urban area
Science Teaching	3 hours per week/half day
Curriculum	Specified by district

Contents

Module 1 - Introducing the Case

Jennie thinks of her young students as curious, eager, natural scientists.

As such, she would like them to look at their world and begin to understand the types of changes that take place throughout the seasons. As part of the study of fall, Jennie hopes that students' curiosity and powers of observation will help these young scientists make associations

between various fallen leaves and the trees from which they came.

Jennie's issues regarding her science curriculum derive from determining what is developmentally appropriate for her students. Should Jennie let misconceptions about a science concept go unresolved? Is it enough for students simply to explore at this age, with less emphasis on developing precise scientific understandings? Can the state framework and national standards help Jennie determine what understandings are appropriate for her students?

Fall Walk Activity

Students visit the same location in the school neighborhood during each season. During their fall walk, Jennie encourages them to notice the changes that take place during this season. After bringing leaves from home, Jennie explains how to classify them according to shape. Jennie's students then place their leaves on a large classroom graph, according to the tree from which they came. The class discusses some of the characteristics of the leaves.

Discussion Questions

What issues do Jennie's approach to and ideas about science teaching and learning raise for you?

On what basis do you think a teacher should decide on goals for science teaching and learning?

How would you address broad curriculum goals, such as those found in many state and national guidelines, to increase the chances that students will build specific scientific understandings?

Module 2 - Trying New Ideas

Fennie meets with Anita Greenwood, a science educator at the

University of Massachusetts, Lowell. They discuss the value of identifying the depth of understandings that students bring to class and build upon ,and linking those understandings to one another.

When designing activities around specific content and process goals, Jennie can refer to Benchmarks, state frameworks, and national standards. Each is a useful barometer that Jennie can use to evaluate her curriculum, having the confidence to know that what she is teaching is developmentally appropriate.

Jennie is well aware that reading and mathematics are considered as disciplines where differences in students' developmental levels are expected. She begins to think that educators should consider science in the same way. Jennie decides that she will put more emphasis on involving students in exploring science with careful attention to specific content and process goals.

Winter Walk Activity

As part of their winter walk, Jennie's students collect snow. Continued study of the seasons provides a context for students to develop understandings about solids and liquids and how matter changes state. Students discuss outside what will happen when the snow is brought into the building. Students share their ideas and predictions. Jennie and her students put samples of snow near the heater, in the freezer, in the refrigerator, on the steps outside, and in the middle of the room at the science center, then observing what happens and comparing the results to their predictions.

Discussion Questions

Which aspects of the winter walk activity do you think help make it possible for students to develop scientifically accurate ideas? Which allow for developmental differences?

What do you consider to be the benefits of using references such as

Benchmarks, state frameworks, or national standards when developing and evaluating a science curriculum? What are possible hindrances?

How might adopting a long-term vision that recognizes the developmental nature of science learning affect your approach to teaching? How might it affect your students?

Module 3 - Reflecting and Building on Change

Spring brings the study of seeds and plants to Jennie's classroom.

Recognizing that less is more, Jennie is less concerned about each student's knowing the parts of a seed and the details of a plant's life cycle, being more concerned about the larger concept of like seeds producing like plants.

As a way of coordinating between grades, Jennie meets with Pat, a first grade teacher in the school. Together, they reflect on what Jennie's students have done this year in kindergarten and how their understandings will serve them next year in first grade. Jennie learns that the drawings students are making in their science notebooks help build the foundation for future science learning. Furthermore, Jennie feels more comfortable with activities that serve to confirm through scientific processes the knowledge that students bring with them.

Seeds and Plants

Groups of students familiarize themselves with seeds by sorting them. Later, students select a seed that they would like to grow and draw the plant that they believe will sprout from this particular seed. To test their predictions, students plant seeds, observe their growth, draw the plants as they sprout and grow, and then place them into groups based on leaf similarities.

Discussion Questions

In your opinion, what made it possible for Jennie to determine the extent of her students' understandings about seeds and plants?

What do you think can make it possible for students to extend their scientific understandings beyond those focused on in a classroom activity?

How would you coordinate your science curriculum between grade levels?

Case Studies in Science Education

Linda — Grades 2-4

Name	Linda
Experience	15 years as a classroom teacher; first year in the position as science specialist
Grade & Subject	K-4 science
Classroom	Urban elementary school
Demographics	Visits all K-4 classrooms in school; total of more than 600 students
Curriculum	Specified by the district

Contents

Module 1 -- Introducing the Case

In her position as science specialist, Linda is responsible for both direct instruction in science through regular visits to each of 26 classrooms, as well as ongoing support of classroom teachers in their own science teaching and learning. One of her primary concerns is how to deal effectively with students' ideas, specifically, how to facilitate scientific understandings through higher order thinking skills and designing fair

experiments.

While working with a second-grade class, Linda challenges her students to explain why a dropper enclosed in a bottle of water rises and falls as students squeeze and release the sides of the bottle. With this activity, Linda realizes that it can be difficult to move students from their own, sometimes scientifically inaccurate, understandings to those that are more scientifically accurate. After groups of fourth-grade students gather materials and try to design fair experiments to answer a question about which surfaces snails "prefer" to move on, Linda begins to explore better ways in which she can help students design experiments in order to construct scientific ideas from hands-on activities.

Cartesian Diver Activity

Students are given bottles filled with water and an eyedropper. Groups are asked to squeeze and release the bottle, making the eyedropper, or "diver," rise and fall. Groups then discuss with one another and with Linda what makes the eyedropper move.

Snail Experiment

Students design experiments to answer the question "What do land snails like to walk on?" Sand, water, sawdust, aluminum foil, and waxed paper are offered as surfaces for students to use when designing their experiments and carrying them out with land snails.

Discussion Questions

What aspects of the Cartesian Diver activity would seem most likely to contribute to the development of scientifically accurate ideas? Scientifically inaccurate ideas? What aspects of the Snail experiment?

If one goal of science teaching and learning is to help students build scientifically accurate ideas, then what do you think must be taken into account when designing and implementing science activities?

If one of your goals were to help students learn what it means to design a "fair" experiment, then how would you address this goal?

Module 2 -- Trying New Ideas

Linda meets periodically with Anita Greenwood, a science educator at the University of Massachusetts in Lowell and a professional development consultant for Linda's district. Together they elucidate some of the ways that teachers can design activities that reduce the possibility that students will build non-scientific ideas. This includes refining the approach to science experiments to ensure that they are "fair" that is, that they produce scientifically valid data.

In a fourth-grade class, Linda works with the classroom teacher, Jean, to design and troubleshoot an experiment that will help students understand that machines make work easier. Although students record their data, the unit of measurement for recording the results, as well as the direction of the numbers from top to bottom on the scales constructed by students, varied among groups.

Jean and Linda decide that one way to help students build more accurate understandings is to focus on controlling more variables. When repeating the experiment, both teachers want students to understand why such factors as too many variables or an inferior apparatus can interfere with building scientifically accurate understandings.

Inclined Plane Experiment

Students test how effort, which to them represents work, is affected by the use of an inclined plane. After hanging weights in a plastic bag that moves along a scale on a piece of cardboard, students pull the apparatus up an inclined plane, record their data, and try to determine if simple machines reduce effort.

Discussion Questions

How would you critique the Inclined Plane activity with regard to helping students build scientifically accurate ideas? Scientific ways of finding answers to questions?

What are the strengths and weaknesses of activities that focus primarily on having students find "the right answers?" Those that focus primarily on having students learn and practice scientific process skills?

In your opinion, what would be the appropriate course of action when students hold scientifically inaccurate ideas after doing a science activity?

Module 3 -- Reflecting and Building on Change

Knowing that too many variables in an experiment can contribute to its not being considered fair in a scientific sense, Linda has refined her ideas about the experiments her students will design and conduct.

She and her students have seen in previous experiments how the number of variables, distracters such as sandwich bags covering a scale, and inconsistent units of measurement for recording data all interfered with fairness, as well as the ability to pool, compare, and make sense of data.

Linda challenges fourth-grade students to design a round of experiments to determine whether mealworms prefer a light or dark environment. By frequent return to the central question, Linda believes that students will be helped to design a fair experiment. Also, students present their designs to the whole class and invite feedback, especially that pertaining to variables. Linda is encouraged by the caliber of the students' feedback to one another and looks forward to building upon what she and her students have learned about designing experiments with other classes.

Mealworm Experiment

Groups of students use flashlights, cardboard tubes, straws, and other materials to design experiments that will help answer questions about the environment preferred by mealworms. Each group presents its design to the whole class and invites feedback about its fairness. Groups consider the feedback and revise their designs accordingly before actually conducting the experiment.

Discussion Questions

What do you consider to be the most significant differences between the Snail experiment and the Mealworm experiment? The Inclined Plane activity?

What do you consider to be the appropriate balance between activities designed to focus on specific science understandings and those designed to build an understanding of scientific methods of investigation?

What aspects of Linda's case study do you find to be most useful in our own science teaching and learning situation? Least useful? Why?

Case Studies in Science Education

Margarita — Grades 5-8

Teacher Profile

Name	Margarita
Experience	First year as middle grades science teacher
Grade & Subject(s)	Grade 5 - 8 bilingual teacher in all subjects
Classroom	Bilingual, mixed grade levels, 13 students
Demographics	Urban middle school
Science Teaching	2 days per week
Curriculum	Specified by district
Other	Taught primary grades for the past four years

Contents

Module 1 - Introducing the Case

As she looks back on her own education, Margaritaacknowledges that she was moved from a Spanish-speaking environment to an English-speaking classroom without adequate transition. Today, as a teacher of all

subjects in a bilingual program, she works with middle grades students who are part of a transitional program intended to move them from native language-speaking classrooms 75% of the time to full immersion after three or four years.

Because this is Margarita's first year teaching at these grade levels, she works closely with Ilia, the district science staff developer. Cooperatively, they explore materials and plan lessons. In addition, Ilia serves as a model by regularly acting as lead teacher during a unit of study. Margarita also co-teaches once per week with Rita, a seventh-grade science teacher. This peer support strategy helps Margarita gain more confidence in teaching science through the kits provided by the district.

Variables Unit

Using commercially made materials, students build a model plane and then use it as a means of exploring the function of variables in a system. By manipulating different variables in the same structure, students discover by experimentation what the variables are, explore some of the ways in which they can manipulated, observe the results of the manipulation, and plan new manipulations to achieve a desired effect.

Discussion Questions

What do you consider to be the most critical issues with regard to science teaching and learning among students with limited English proficiency? Why?

What types of support do you feel you would need to teach science in a setting where there are limited English proficiency students?

How do you think teachers of limited English proficiency students can address the concern that they keep pace with their peers in terms of their understandings of science?

Module 2 - Trying New Ideas

Margarita explains that she wants to continue with the Variables Unit after completion of the commercial materials. She hopes that with an open-ended investigation in which students decide upon the system (planes, boats, catapults, or pendulums) that they will study, students will develop expertise in that system.

As an assessment of the depth of students' understanding of variables, groups experimentandf then express and share their ideas using appropriate science vocabulary. This culminates in the delivery of an oral presentation by each group to the class.

Variables Presentation

Using what students know from the previous unit on variables in planes, boats, catapults, and pendulums, students decide upon one system to investigate in more depth. Relying on one another, group members then choose a variable within that system to explore in greater depth. Groups design experiments to test their hypotheses, prepare tables and charts to display their data, and give oral presentations to the class.

Discussion Questions

What do you consider to be the strengths and the weaknesses of the Variables Unit with regard to science teaching and learning among limited English proficiency students? Among any group of students?

In your opinion, what factors may prevent students from being able to think and communicate in science? What facilitates this ability?

How would you assess whether or not science teaching and learning was effective among limited English proficiency students?

Module 3 - Reflecting and Building on Change

Margarita's class is now studying the human heart as part of their study of the human body system. Four stations have been assembled at which students can either view a demonstration of a preserved calf's heart, simulate the heart's pumping action with a tennis ball, measure their pulse, or investigate the amount of blood that the heart pumps in a given time.

Because four grade levels are represented in her science class, Margarita is very aware of offering her students varied opportunities to explore and experience scientific ideas at different levels. For example, an eighth-grade student decided to conduct independent research on the heart. She became the class heart expert and chose to write a report and make accompanying charts and illustrations, using English. Margarita also recognizes the importance of encouraging group work wherein peers serve one another as resources for learning and of selecting units that are not biased toward a particular culture or language.

Human Body Systems

Students explore the human heart as part of a more global study of systems. Four stations are set up in the classroom. They include a heart demonstration that is facilitated by a seventh-grade science teacher; a heart muscle investigation wherein a student's squeezing a tennis ball for a given time simulates the heart as a muscle; a pulse-taking station where students measure their heart rate; and a volume station where participants model with tubs of water the volume of blood the heart pumps in a given time.

Discussion Questions

How did Margarita's relationship with her peer support teachers evolve throughout the year?

What criteria would you use to select or adapt curriculum materials for use with limited English proficiency students?

How would you take into account students' diverse linguistic, cultural, and academic backgrounds as well as future goals when planning for science teaching and learning?

Case Studies in Science Education

Mike — Grade 7

Teacher Profile

Name	Mike
Experience	27 years
Grade & Subject(s)	Grade 7; life science
Classroom	25 students per class; 50% male, 50% female
Demographics	Middle school in a suburban district
Science Teaching	Two classes, 10 hours per week
Curriculum	Specified by district
Other	Team leader; Science department head

Contents

Module 1 - Introducing the Case

After more than 20 years of teaching, Mike has observed several differences in the way that boys and girls participate in science class. He is also aware of the statistics documenting the under-representation of

girls in most science fields. This year, Mike hopes to learn more about gender issues in science and to apply what he learns to his own practice.

Grass Infusion Lab

Working in pairs, students conduct a simple experiment to determine what happens when grass is added to a jar containing previously boiled water. Mike introduces the grass infusion as an example of a laboratory system and asks students to track changes over time. Students compare the infusion with a control jar, which contains only water.

Discussion Questions

Based on your own experiences, which of Mike's theories about the differences between boys and girls in science do you agree with? Which do you disagree with? What other theories can you add?

In your opinion, how might the "structure of the science" be responsible for keeping girls from "going into science?" How might "the way it's taught" be responsible?

Where would you start if you wanted to learn about and address gender differences in science?

Module 2 - Trying New Ideas

Mike visits with Sheila Cronin, a high school science teacher in a neighboring town. Sheila is also committed to understanding more about gender equity in the science classroom and shares with Mike the idea of

group work as one way to learn about and accommodate gender differences. They exchange ideas about the value of maintaining single gender work situations, but Mike's ultimate goal is to have both genders work together successfully.

Because students have previously opted to work almost exclusively in single gender groups, Mike decides to help students develop better group skills before encouraging boys and girls to work together through all phases of science study. As part of a listening skills activity, single gender pairs describe to one another details involved in building a cell model from household materials. Listeners then rephrase what they were told. Later, pairs of girls and pairs of boys present to one another a diagram representing how each pair has classified a group of single-celled organisms. Each pair then offers the other positive feedback about their work and notices differences in approaches to the task. Class members share with the full class their observations of what was appreciated in the presentations and work product.

Protists Activity

As part of a study of the Protist Kingdom, pairs of girls and boys develop a diagram representing their understanding of the similarities and differences among members of this large and diverse biological group. Each pair of boys then joins a pair of girls to share their work and to provide a supportive critique.

Discussion Questions

How would you critique the strategy of focusing on cooperative group work as one way to foster gender equity in the science classroom?

When do you think it is appropriate to encourage or assign single gender groups? Mixed gender groups?

What other aspects of science teaching and learning would you focus on in the interest of fostering gender equity?

Module 3 - Reflecting and Building on Change

As the year comes to a close, Mike's science class moves outdoors and becomes involved in an ecological study of a parcel of land, or plot study. Mike wants to observe how boys and girls will work together. He does not instruct students to work in groups of mixed gender, but he does suggest it. By allowing students to make their own choices in selecting working groups as well as allowing substantial independence in designing their studies, Mike believes that both boys and girls will become more self-motivated.

The resulting mixed gender groups assign each member a specific role; however, members readily share roles when it helps the group accomplish the objectives of the study. Mike also provides students with an opportunity to make meaning of their work by allowing time for individuals to think and write before working with group members to prepare a presentation for the class. As a part of this, students are asked to consider how their work might be used in real-world situations. Mike hopes that by providing students with more reflective time, as well as an opportunity to see how their work might make a difference, he can continue to work toward gender equity in science teaching and learning.

Plot Study

As a long-term project, groups methodically investigate a sizable square parcel of land on school grounds to determine the nature of the living and non-living environments there. Groups ask and seek answers to their own questions and determine how their findings might be useful in solving real-world problems.

Discussion Questions

What aspects of the plot study do you think best address goals for gender equity in the science classroom? What improvements would you suggest?

What do you think indicates that the needs of girls are being met in the context of science teaching and learning? The needs of all students?

What questions does this case study raise for you with regard to the gender issue in science? How might you go about finding answers by conducting research in your own classroom?

Case Studies in Science Education

Najwa and Pat — Grade 1

Teacher Profile

Name	**Najwa & Pat**
Experience	**24 years and 22 years, respectively**
Grade & Subject	**Grade 1, all subjects**
Classroom	**Elementary school in an urban district**
Demographics	**40 students, 20 students per class, 6 special needs students**
Science Teaching	**5 meetings per week**
Curriculum	**Specified by district**

Contents

Module 1 -- Introducing the Case

Pat and Najwa are first grade teachers in adjacent classrooms. They teach in an inclusion setting, where special needs children receive additional help from a para-professional and become integrated as much as possible into the learning activities of the whole class. Both Pat, who is trained as a special needs teacher, and Najwa, who is a regular classroom teacher, believe that the larger school community plays an important role in their students' education. They combine classes and invite aides, student teachers, and fifth-grade volunteers to work alongside their students for an ambitious science activity consisting of simultaneous stations on the theme of animal habitats.

Najwa and Pat want students at the first grade level to experience the processes of science and to make ties between science learning and other subject areas. The two teachers meet before and after school to share ideas and plan team-teaching activities. By working together, both teachers hope to design science activities appropriate to the range of abilities in their classrooms and to find ways of involving the school community by recognizing that "it takes an entire village to raise a child."

Animal Homes

In Pat's class, students listen to stories such as The Mitten, to learn more about animal homes during winter. Najwa's class focuses on the adaptations that animals make to their winter homes.

Discussion Questions

How have Najwa and Pat put into practice the idea that it "takes an entire village to raise a child?"

What would you consider to be the most important challenges of science teaching and learning in an inclusion setting?

What strategies would you use to try to meet the needs of all students?

Module 2 -- Trying New Ideas

During their planning together, Pat and Najwa have decided to integrate a home-school component in their science teaching and learning. To launch the activity, teachers and students meet in the library and discuss the project and distribute materials that students will take home.

As part of the study of plants and their seeds, students are asked to work at home with their family to (1) identify fruits and vegetables, (2) look for the seeds within them, (3) count the number of seeds and draw their shapes, and (4) compare numbers of seeds. Students are asked to bring the seeds to class. After the seeds are classified and sorted by shape and size, students construct, read, and interpret bar graphs.

Najwa and Pat believe that activities such as this encourage a closer relationship between teachers and families and encourage students to begin assuming responsibility for their own learning. Strengthening the

connection between the learner, his or her family, and the school benefits the students by expanding the community that supports the child in the science classroom.

Seed Project

After identifying the different types of fruits and vegetables from pictures, students work with family members to classify fruits and vegetables found at home. With adult help, students (1) cut open the fruits and vegetables and draw them, (2) look for the seeds inside and count and draw them, and (3) bring the seeds to class. Later, students construct bar graphs comparing the numbers of seeds.

Discussion Questions

How do you think the seed project aligns with Najwas and Pat's philosophy that education requires the support and participation of a child's community? How do you think it aligns with meeting the needs of all students? How might an activity like this be changed to address both goals?

What do you think is most important when designing activities that aim to connect science learning at school with science learning at home?

Using science content appropriate to your situation, what types of home-school activities would you design?

Module 3 -- Reflecting and Building on Change

Toward the end of the school year, Najwa and Pat decide to move their science lessons outdoors. Continuing with the study of plants and their seeds, Najwa and Pat have enlisted the help and support of parents, fifth-grade students, and other teachers to establish stations for students to visit.

There is a writing station, led by Pat; a seed classification station; a shopping station, where students use their mathematics skills when weighing and buying fruits and vegetables; and a planting station, where students plant seeds in terrariums.

Najwa and Pat will encourage their students to record their observations on plant growth during the summer. This is another way of involving community, or village, in its students' learning.

Outdoor Science Stations

Parents, fifth-grade students, and other teachers participate with students at three stations where students classify seeds, shop for fruits and vegetables, and plant seeds.

Discussion Questions (this is larger heading)

What issues does Najwas and Pat's approach to science teaching and learning in an inclusion setting raise for you?

As a strategy for meeting the needs of diverse learners, what do you consider to be the advantages and disadvantages of letting students participate in designing activities?

How do you incorporate the idea that "it takes a village to raise a child" into your science teaching and learning?

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Case Studies in Science Education

Nancy — Grade 8

Teacher Profile

Name	Nancy
Experience	5 years
Grade & Subject	Grade 1; all subjects
Classroom	Junior high school in an urban district
Demographics	20 students
Science Teaching	5 classes; each class 5 meetings per week
Curriculum	Specified by district

Contents

Module 1 -- Introducing the Case

Nancy believes that one of her primary responsibilities as a teacher is to ensure that her students do their best. The issue that Nancy faces is that of encouraging her students to become independent thinkers and to use a scientific approach when solving problems. Until now, Nancy has observed that her students look to her for answers to questions and solutions to problems. Nancy wonders if her students will become more self-directed if they are presented with a problem to solve and are then asked to form an appropriate question, propose a hypothesis, test their ideas, analyze results, and draw conclusions- all as part of solving the problem.

To help enable this scientific approach, Nancy realizes that students need to understand that there is a process to finding answers to scientific questions. This process can, and often does, include wrong answers and unsatisfactory solutions to problems along the way. As a means of implementing her ideas, Nancy guides her students through a scientific approach in a chromatography lab activity in which students determine the colors that compose an ink marker.

Chromatography Activity

As part of their study of chemistry, students are learning about the properties of solutions. Using lab materials and chromatography paper, pairs of students separate colors to determine which color dyes compose the ink in a marker.

Discussion Questions

What do you consider to be the most compelling evidence that change is needed in Nancy's classroom?

In your opinion, what factors contribute to a situation where students depend heavily upon the teacher to guide them through a problem-solving situation and/or provide them with solutions?

How do you conceptualize your role as a teacher in the science classroom? The role of your students?

Module 2 -- Trying New Ideas

Nancy meets with Phil Sadler, a teacher educator from Harvard-Smithsonian Center for Astrophysics. Phil is the Principal Investigator for Project DESIGNS-a project-based engineering curriculum. Nancy is one

of the teachers piloting the program before final publication. Together, they explore how using metaphor as a way of reconceptualizing teacher and student roles might lead to more self-directed learning.

Nancy adopts the "Project Manager" metaphor with her class as they work together in groups to construct motors, following a unit focusing on electricity and magnetism. Students serve as members of a team that is charged with building a motor. They are to rely on one another when seeking answers to problems, and a "runner" seeks out Nancy only as a last resort. Nancy and Phil try to find a way to use this new curriculum to help Nancy's students become more independent learners.

Nancy hopes that by engaging her students in this sort of real-world work environment, combined with a design-to-constraint problem they will use higher-order reasoning skills and become more self-directed learners.

Motor Project

After students are successful in building a simple motor given a standard design, they are challenged to make changes to the design so that the motor goes faster. The activity concludes with students reporting their results and explaining how they were achieved.

Discussion Questions

What do you consider to be the most significant changes associated with the use of the Project Manager metaphor during the motor activity?

What situations do you think foster more self-directed learning in a science classroom?

What do you think are the strengths and weaknesses of an engineering curriculum in promoting self-directed learning?

Module 3 -- Reflecting and Building on Change

Because problem-based learning in science strives to engage students in applying their basic science knowledge to solve a more complex problem, students are encouraged to share their ideas as well as to find different pathways to a solution. The process whereby students express ideas, debate their merits, and then test these ideas is central to science.

A simple design problem involving limited numbers of variables is the source of Nancy's final project-based activity. As students are challenged to design the most efficient weight-bearing paper truss, they offer technical support to one another and find the answers for themselves. Again, Nancy uses metaphor in her teaching-this time as chief engineer.

Paper Truss Activity

At the end of the year, Nancy introduces a final "design-to-constraint" activity. Given one sheet of paper, students are challenged to trim away as much paper as possible, while using what remains to support a lead weight.

Discussion Questions

Using the Motor Project and the Paper Truss Activity as examples, what do you think the criteria are for a project that helps foster self-directed learning in science?

In your opinion, what is the appropriate balance between a problem-solving approach and other approaches to science teaching and learning?

In a content area appropriate to your classroom, what sorts of design-to-constraint (engineering problems/projects) could you develop? What metaphor might you use to accomplish your goals for your students?

Case Studies in Science Education

Pat — Grade 8

Teacher Profile

Name	Pat
Experience	21 Years
Grade & Subject(s)	Grade 8; Life Science and Social Studies
Classroom	48 students; 20 % special needs
Demographics	Middle school in a suburban town
Science Teaching	Two classes, 40-minute periods, 5 times per week
Curriculum	School is moving toward an integrated science ("spiraled") curriculum; district specified; 8th-grade team leader
Other	Shares classrooms with other teachers; does not have his own classroom

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Module 1 - Introducing the Case

The issue that Pat shares with us involves his desire for students to undertake authentic scientific investigations. That is, as students explore "mystery labs," Pat wishes for them to grapple with ideas as scientists do, asking questions and independently leading themselves to the next steps in a study. Pat feels frustrated by the fact that his students still rely on him to prompt them to the next scientific "discovery" and feels as though these prompts detract from his goal of students' questions and explorations driving his lessons. Pat challenges himself to find other ways to encourage inquiry-based learning in his middle grades science classes.

Apple Study

Apples serve as the context of students' exploration of biological structure and function. Pat gives students apples to dissect as a way to promote scientific investigation. Students record their observations and then answer questions on a lab sheet.

Discussion Questions

Which aspects of Pat's "mystery labs" are most supportive of an inquiry-based approach? Which aspects are least supportive?

What role do you think inquiry-based labs should play in a science course? Why?

How would you design labs to be more inquiry-based?

Module 2 - Trying New Ideas

Pat meets with Rick Duschl, a science educator from Vanderbilt University. Together, they consider ways that Pat can promote student-

driven inquiry while still providing a focus to his "mystery labs." Specifically, they discuss how to design labs around encompassing scientific ideas. For example, students may dissect an apple to consider how its structures relate to the function of reproduction.

Pat adapts this strategy to an investigation of chicken wings in a comparative anatomy unit. The overarching question becomes how the parts of a wing lend themselves to the function of flight. As students dissect the wing and record their observations, they keep the function of flying in the forefront of their minds. This central question of flight helps keep the mystery alive and encourages students to raise questions that occur as they dissect the wing. Using prompts and cues, Pat tries to achieve his goal of having his students leave his science classes with the sense that the students themselves have discovered something - that they are science experts.

Chicken Wing Study

Working together, pairs of students dissect a chicken wing and make observations about its parts to learn more about how structure plays a role in the function of flight. Questions that arise during the course of the study are recorded and discussed in a whole-class setting.

Discussion Questions

How would you describe the differences between the "apple study" and the "chicken wing study?"

In your opinion, what are the strengths of providing an overarching question as a way of structuring student inquiry? What are the weaknesses?

How might students represent their results from a lab in a manner consistent with an inquiry-based approach?

Module 3 - Reflecting and Building on Change

To align with his goals for students as experts, Pat introduces his students to another way of representing what they have learned and understood - pamphlets similar to those printed by public and private organizations. The pamphlets that students create answer some of the "big questions" and explain other understandings that students have developed while dissecting.

Pat's students continue to investigate the relationship between biological structure and function by focusing on human body systems. During their study of the respiratory system, Pat precedes an investigation of healthy vs. diseased lung tissue by asking his students to write one question that comes to mind. Students work individually, using microscopes to view commercial slides of three types of lung tissue: healthy, showing evidence of emphysema, and showing evidence of cancer. Pat revisits the students' questions after the lab and prompts discussion about them as a way of showing students how scientists answer questions based on scientific investigation. By using questions generated by the students to give focus to the lab, Pat continues to work toward his goal of student-driven inquiry. As Pat continues to refine his future "mystery labs," he hopes to increase the extent to which students' questions drive scientific inquiry.

Lung Tissue Study

As part of their continuing study of biological structure and functions, students use microscopes to compare healthy and diseased human lung tissue.

Discussion Questions

How would you describe the differences between the "chicken wing study" and the "lung tissue study?"

What role should students' questions and answers play in an inquiry-based activity? What role should the teacher's questions and answers play?

Which aspects of Pat's evolving mystery lab approach would you incorporate into your own teaching? Which aspects would you modify? Why?

Case Studies in Science Education

Patricia — Grade 1

Teacher Profile

Name	Patricia
Experience	20 years
Grade & Subject(s)	Grade 1; all subjects
Classroom	75% white; 25% non-white
Demographics	Elementary school in a suburban town
Science Teaching	2 hours per week
Curriculum	Specified by district

Contents

Module 1 - Introducing the Case

Pat wants her students to feel like scientists when doing science. That is why students don name tags of famous scientists when activities begin. As the class begins a unit on fish, these young scientists are encouraged to use all of their senses when making observations.

With science, Pat likes to break away from paper and pencil tasks that are often the primary emphases in other subject areas. She wants her students to experience science in a hands-on way that they can talk about, as well as write about. The issue this raises for Pat is increasing the extent to which learning is active and student-centered in her classroom.

Fish Activity

In preparation for a field trip to the local aquarium, students offer questions regarding fish and their behavior. Next, groups observe goldfish without and with magnifying lenses and share observations. After viewing an overhead transparency of a fish with its external parts labeled and their functions described, Pat asks volunteers to color given parts on a large chalkboard diagram. Finally, students label and color individual fish diagrams.

Discussion Questions

What do you consider to be the strengths and weaknesses of Pat's use of the fish activity with regard to actively involving each student in science learning?

How do you think that moving from individual to group-oriented work might increase the physical and mental involvement of students in science activities?

How would you redesign this fish activity to maximize the extent to which learning is student- centered?

Module 2 - Trying New Ideas

Pat meets with Anita Greenwood, a science educator at the University of

Massachusetts, Lowell. They discuss the strategy of using group work as one way to encourage student-centered science learning and the fact that children need to learn the skill of working together just as they learn any other skill.

Pat begins by asking students to work in pairs as the class starts a unit on the human heart. Pat observes that shy, more reticent students seem more willing to share their ideas with a peer than the full class. Later, as students begin exploring their heart rate and its change with increased activity, Pat asks her students to become involved by measuring their own pulses or each other's and recording the results. This activity-based learning is encouraging to Pat because the activity is something that students did and interpreted themselves. Pat looks forward to moving from partner to larger working groups.

Heart Study

When beginning the unit, Pat elicits from students their prior understandings about the human heart. Pairs of students then use cardboard rolls, funnels with tubing, and stethoscopes to listen to one another's heart beat. Later, students take their pulses during three levels of activity: while seated, while walking, and while jumping in place. Each time, students record and discuss their results as a full class. Finally, each student uses crayons on a large cut out of the human body to make distinctions between parts of the heart and the blood flow to and from it.

Discussion Questions

How do you think that Pat's use of partners in the human heart activity contributed to her goal for more actively involving her students?

If you were the classroom teacher, how would you assess students' group skills as they worked on the heart activity?

Once students are successfully working with a partner, how would you begin the process of working in larger groups?

Module 3 - Reflecting and Building on Change

Pat's students can be seen actively working together and can be heard sharing their findings. Groups of students collaborate to observe, sort, and classify seeds. Sprouting lima beans in plastic bags and charting the seedling's growth is a long-term project that enables students to see for themselves what happens to the roots as well as the sprout.

Students dissect seeds to identify the various parts. Finally, students make clay models to show their understandings of the physical characteristics of a sprouting seed.

Through watching her students work together in small groups, Pat continues to see the value of using cooperative group work to foster a student-centered science curriculum.

Seeds and Plants

Groups of three sort and classify seeds according to type, size, shape, color, and texture. As part of an ongoing activity, each student sprouts a lima bean in a plastic bag. Students observe this example of a sprouting seed and record its growth on individual graphs and write about the sprout in a seed journal. Students dissect different types of seeds, identify their parts, and apply appropriate scientific terminology. As a culminating activity, students make clay models that show their understandings of the parts of a bean sprout.

Discussion Questions

In your opinion, what are the most significant changes evident in Pat's classroom with regard to making science teaching and learning more student-centered?

What do you think are the challenges a teacher faces when using

cooperative group work as a strategy for making science more student centered? How would you address these challenges?

In what circumstances is small group work most appropriate? When and why would you use individual and full class work within science lessons?

Case Studies in Science Education

Raquel — Grade 7

Teacher Profile

Name	Raquel
Experience	6 Years
Grade & Subject(s)	Grade 7; earth science
Classroom	Approximately 150 students; multiethnic
Demographics	Urban school requiring admission test
Science Teaching	42 minutes, 3 days; 30 minutes, 2 days. Use of lab room, scheduled one time per week
Curriculum	Representative middle grades earth science curriculum, with textbook as a guide
Other	Undergraduate and some graduate study in geology; EdM in Teaching and Curriculum

Contents

Module 1 - Introducing the Case

"...Since I have a homeroom and keep a hamster there, I find that kids want to be in my classroom more..." With those words from Raquel, we learn something about the extent of Raquel's involvement with her students. In an effort to help her students see the sun as a dynamic, changing body rather than a fixed object in space, Raquel encourages partners to explore, explain, debate, and defend their opinions and ideas with one another. Raquel is not dissuaded by the sort of bickering that this often entails, but would like to take that discussion and extend it to a more formal expression of opinion and defense of that opinion based on scientific evidence. Raquel has noticed that open classroom discussions can be intimidating for students who lack confidence in their abilities or verbal skills. Raquel also observes that girls and students of color may be less comfortable talking about science, even though they have ideas to offer.

Sun's Rotation Activity

As part of a unit on the solar system, students look at photographs of sun spots taken over a 30-day period. By comparing the movement of the sun spots at different latitudes across the face of the sun, students try to determine the rotation periods at those latitudes. These observations help students learn more about the sun's rotation and understand that the sun is a dynamic, celestial body.

Discussion Questions

Which aspects of Raquel's approach to the sun spot activity might have a differential impact on the attitude or understanding of students typically underrepresented in science?

In your experience, what practices in science education do you think are likely to be exclusionary toward girls and /or students of color?

What are some ways for teachers to increase opportunities for girls and students of color to become confident and competent in science?

Module 2 - Trying New Ideas

Raquel knows from observing her students that girls need space to talk.

Tom Dana of Pennsylvania State University and Raquel talk about extending the journal writing that students already do as a way of offering them more space to discuss their ideas about science. By asking students to comment in writing in one another's journals, thereby creating a dialogue journal, Raquel can offer another form of communication among peers. As a way of introducing students to the idea, Raquel asks each student to write a weather story, which is shared and commented upon by a classmate. Raquel comments that girls are now writing and talking more about science ideas and opinions. Raquel thinks the dialogue journals have offered the venue some of the girls needed to express themselves. In an effort to build upon this dialogue, Raquel encourages longer, more detailed, written discussions as a way of helping students learn more through exploration of their own theories.

Weather Dialogue Journal

Students write about their scientific ideas and opinions in journals, which students exchange partners for their written responses. Some entries require students to design experiments to prove theories regarding the properties of air, some require students to explore hypotheses relating air pressure to weather conditions, while others involve creative story-writing about weather's impact on our lives.

Discussion Questions

In your opinion, what are the most promising aspects of dialogue journals with regard to improving science teaching and learning? The most problematic?

Why might creating additional space for dialogue be a good strategy for fostering connectedness, confidence, and competence in science in students who are typically underrepresented at advanced levels?

What are some other ways teachers might engage students in meaningful dialogue about science concepts?

Module 3 - Reflecting and Building on Change

Because of the lack of depth in the written responses in the dialogue journals and the informal and unstructured nature of journal writing, Raquel decides to supplant the written dialogue strategy by asking her students to conduct face-to-face interviews with one another. In this way, students can role play as a means of seeing how scientists think and grapple with ideas. Students work in pairs to create news-like reports about events such as earthquakes on audiotape, videotape, or in print. This role play, often with technology integration, lends even more structure to students' dialogue and different kind of space for exploration and discussion of science concepts.

Raquel notices that the interview tapes act as a resource that students can use when they reflect on what they have learned and how their ideas have changed over time. Raquel attributes some of the success of the interview project to the self-confidence that students gained in their ability to talk about science by means of the dialogue journals.

Interview Project

As part of the study of the earth's internal geological process, students conduct interviews with one another to explain their understandings about the connections among such phenomena as earthquakes, volcanoes, and plate tectonics.

Discussion Questions

How would you compare the interview project with the dialogue journal in terms of the potential for each to foster positive attitudes toward and understanding of science concepts?

What conditions are necessary for meaningful and productive dialogue to occur as a part of science teaching and learning?

How would you foster positive and productive experiences for girls and students of color in science?

Case Studies in Science Education

Jo-Ann and Richard — Grade 2

Teacher Profile

Name	JoAnn and Richard
Experience	Combined, 40 years
Grade & Subject	Grade 2; all subjects
Classroom	Elementary school in a suburb
Demographics	Combined, 40 students
Science Teaching	Daily
Curriculum	Specified by district
Other	Piloting integrated mathematics and science program; offering professional development to colleagues

Contents

Module 1 -- Introducing the Case

Following four weeks of intensive summer training in integrating mathematics with science and other subject areas, Jo-Ann and Richard implement what they have learned in their classrooms. Richard chooses to integrate literature, science, and mathematics by means of reading aloud the story of Johnny Appleseed and then asking students to describe and to classify four varieties of apples. Following a taste test, students record their favorite, predict the most popular, and then graph their results on a class picture graph.

Jo-Ann decides to integrate the mathematics skill of recognizing coins and understanding their values with science in an activity where students estimate, then find the actual number of drops of water that will fill the surface of a coin without overflowing. Students compare their findings and propose ideas about the nature of water to explain what happened.

How Many Drops?

Each student estimates how many drops of water the surface of a nickel and a penny will hold before the water overflows. Next, using an eyedropper, students find the actual number to check their estimates, always recording their data. A worksheet serves as a bar graph to compare the estimates with the actual number of drops for each coin.

Discussion Questions

How would you compare the Apple Tasting activity and the "How Many Drops" activity with regard to the effective integration of science and

mathematics?

Given the traditional practice of separating curriculum content areas, what do you think are the greatest challenges in integrating science and mathematics?

What criteria would you use to assess whether science and mathematics are integrated effectively in classroom activities?

Module 2 -- Trying New Ideas

"Secret formulas" activities provide students the opportunity to use both mathematics and science skills as they become inventors who are challenged to derive formulas, with given ingredients, for making paste and cola. In the process students develop their own problem- solving strategies, make decisions, and communicate findings. These young inventors discover for themselves the attributes of the different ingredients and carry out their own experiments.

Jo-Ann and Richard meet with Dick Konicek of the University of Massachusetts, Amherst. He suggests that by being aware of the potential partnership between mathematics and science in answering questions and solving problems, teachers can help ensure that students realize the value of integrating both disciplines.

Secret Formulas Activities

Students use given ingredients to derive formulas for making paste and cola. This involves making estimates, measuring ingredients, recording data, and graphing results. Students carry out experiments, adjusting formulas to make the best of each item. In the case of the cola formula, the young inventors conduct a taste test, decide upon the best formula, use mathematics to expand the quantities to create enough for the entire class, and then embark on "marketing" their product with a package design and advertising campaign.

Discussion Questions

In the paste formula activity, how would you describe the mathematics component? The science component? The integration of the two disciplines? How would you compare this to the cola activity?

In your experience, how do mathematics and science "fit together?" Under what conditions do you think an "equal partnership" is possible?

What circumstances foster the effective integration of mathematics and science, as well as other subject areas?

Module 3 -- Reflecting and Building on

Change

With summer vacation just around the corner, Jo-Ann and Richard sponsor a Bubble Festival. Parents are invited to assist in bubble activities with students. Stations feature many open-ended investigations of soap bubbles, several of which engage students in using their mathematical skills and understandings. Students rotate through several stations, making bubbles and observing their properties.

As with other activities that are being piloted throughout the school year, Richard and Jo-Ann facilitate a professional development workshop with their colleagues. In critiquing the first Bubble Festival, teachers decide they will try to set up a different management system in the future, freeing up their time for more of those "teachable moments" that can act as catalysts to reaching goals for student understanding.

Bubble Festival

Stations feature soap bubble activities that are designed for students to participate in open-ended, interactive investigations that explore the properties of bubbles.

Discussion Questions

With regard to effective mathematics and science integration, how would you compare the Secret Formulas activities with the Bubble Festival?

Using content that is appropriate to your present or future teaching situation, how would you describe an activity that you feel shows effective integration of mathematics and science? Why do you feel this activity

would be effective?

How can you envision involving colleagues in helping make changes in teaching and learning within your classroom? Within a school?

Case Studies in Science Education

Sarah — Grade 5

Teacher Profile

Name	Sarah
Experience	Five years
Grade & Subject(s)	Grade 5; all subjects
Classroom	23 students; 35% special needs, 55% ESL
Demographics	Outer city elementary school in university community
Science Teaching	1 hour sessions; twice per week
Curriculum	Life, physical, and earth sciences; "kits" adopted by district
Other	Lead teacher for professional development in the use of kits, which are prepackaged curriculum including teachers' guides, BLMs, and materials/supplies for an entire class. Master's degree in education

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Module 1 - Introducing the Case

Sarah's class is in the midst of a unit focusing on scientific variables. As part of the trial of a commercial kit-based curriculum, students have formally explored which variables affect the motion of pendulums. Now, Sarah hopes to offer a more open-ended experience that will allow students to build upon their growing understandings of both variables and pendulums by introducing students to compound pendulums, which are swinging weights suspended from more than one fixed point. Pairs of students use materials to construct a compound pendulum, which is suspended from more than one point. With minimal guidance from Sarah, groups of students use trial and error to construct a compound pendulum that will create an ink design when set in motion. Success is mixed among groups. After the exploration, Sarah facilitates a full-class discussion to help students reflect on the outcomes of the activity.

Later, Sarah's students repeat the activity with more successful results. Sarah continues to see the need for students to draw accurate scientific conclusions from an activity.

Compound Pendulum Activity

As a part of exploring the concept of scientific variables, students assemble compound pendulums. The goal of the activity is to create ink designs by controlling and manipulating the variables involved.

Discussion Questions

What would you describe as the goals of the compound pendulum activity? Which goals were achieved in the first implementation of the activity?

In your opinion, what makes it possible for students to construct scientific understandings from hands-on activities?

How might the compound pendulum activity have been designed differently to increase the possibilities for students to draw scientific conclusions?

Module 2 - Trying New Ideas

Sarah meets with Rick Duschl, a science educator from Vanderbilt University, and discusses the need to assign more importance to the role that data plays in enabling students to construct scientific understandings. Back in her classroom, Sarah encourages pairs of students to observe several foods and then discuss and record their findings on individual data tables. To facilitate the recording process, Sarah has developed a checklist that helps students organize their thoughts and focus their responses.

Later, Sarah invites one member of each pair to record the data from their combined data tables on a class chart, an activity that also serves as a wrap-up to the day's lesson. However, she feels that the data chart, as it is constructed, is somewhat difficult to interpret. Thus, Sarah revises the table before the next class session. Students are then asked to search for patterns in the data and synthesize results.

Sarah continues to make use of individual and class data tables when students test for glucose by using indicator test strips.

Food Chemistry Project

Using the materials in a food chemistry kit, pairs of students make observations of eight foods: rice, flour, apple, egg white, peanuts, granola bar, onion, and coconut. As an introduction, students use their senses to observe and then record their observations. Later, students use test strips to test for glucose in these same foods. A positive test turns the test strip green

Discussion Questions

What do you consider to be the most significant changes that Sarah makes in the potential impact on students' ability to construct scientific understandings from their experiences?

What is your opinion about the importance of data in science teaching and learning?

What aspects of Sarah's new approach would be most useful to you in your classroom? Least useful?

Module 3 - Reflecting and Building on Change

Sarah engages her students as food chemists working in a laboratory, testing marshmallows for their content and considering their nutritional value. Different groups test for different nutrients, then record the groups' findings on a class chart. Sarah then facilitates a full class discussion of the results. The implications of the "food chemists" findings are integrated with real-world experiences, such as consumer appeal based upon nutritional content.

What's in a Marshmallow? Activity

As the culminating activity for the unit on food chemistry, groups of students test marshmallows for the presence of sugar, starch, protein, and fat.

Discussion Questions

How does the marshmallow activity reflect continued change in Sarah's approach to science teaching and learning?

What is your sense of the potential for science kits to both facilitate and limit meaningful learning?

How would you involve students in data collection, manipulation, and interpretation?

Case Studies in Science Education

Terez — Grade 4

Teacher Profile

Name	Terez
Experience	31 years
Grade & Subject(s)	Grade 4; all subjects
Classroom	22 students; 7% special needs; 5% ESL
Demographics	Elementary school in a small college town
Science Teaching	One hour sessions, three times per week
Curriculum	Life, physical, and earth science; District specified
Other	Holds a doctorate in science education; Presidential Award for Excellence in Science Teaching, 1993

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Module 1 - Introducing the Case

The issue that Terez shares with us involves how to assess accurately

what students understand as they progresses through a unit of study. Typically, Terez encourages her students to become active learners by emphasizing cooperative group work. She uses time with each group, along with full-class discussions, to find out what understandings students have from the activities they do.

Following the study of characteristics of rocks, which begins a larger unit on geology, Terez observes in group presentations and accompanying discussion that it is difficult to detect the depth of understanding that she had hoped for from each student. Terez is searching for another way to probe deeper and gain a better understanding of what each student knows.

Rock Classification Activity

Terez encourages her students to investigate and to think like scientists do by asking students to observe some of the characteristics of various rocks and minerals, and then record descriptions of those characteristics on a data sheet.

Discussion Questions

What are the strengths and weaknesses of the rock classification activity in providing opportunities for individual students to learn with understanding? To represent their learning?

What problems does group work present with regard to assessing what individual students learn?

What possibilities does a science folder containing student work offer in assessing individual learning?

Module 2 - Trying New Ideas

Terez meets with Tom Dana, a science educator from Pennsylvania State University, to discuss ways of accurately assessing what individual students know. Together, they strategize how to build upon her use of science folders so that they become more valuable assessment tools. Presently, the folders are collections of papers that represent the outcomes of tasks and exist as a sort of scrapbook.

Terez considers how the folders might include other critical components that suggest student reflection, connections among topics studied, and student ownership.

Sky and Light becomes the unit that will serve as the context of Terez and her students' embarking upon portfolio building. Initially, the science folder serves to help students collect and store their work - a sort of "working portfolio."

As the end of the unit approaches, students have a substantial collection of materials that can be used as resources to help students solve problems, as evidence of their progress in understanding from the beginning of a unit to its end, and as the source for reflection on what students think represents their learning about a topic. Terez wants her students to revisit their portfolios and use the work in them as a resource for extending and connecting their understandings.

Sky and Light Activities

Ongoing activities include weather calendars to track temperature, precipitation, and cloud cover; sunrise and sunset charts to track changes in the amount of daylight from mid- to late spring; and shadow circles to track daily and seasonal changes in the sun's position overhead as indicated by changes in a vertical stick's shadow relative to due North. The materials and representations that are the products of these activities are maintained in a portfolio as resources to be used as evidence of understanding.

Discussion Questions

What prior conceptions do you think Terez and her students have about the role of portfolios in science teaching and learning?

What do you understand to be the distinctions between a scrapbook and a portfolio?

How do you think portfolios can be used to assess what individuals learn? To promote learning?

Module 3 - Reflecting and Building on Change

Teams of students work together, using the work in their portfolios to formulate questions and then to answer one another's questions. Group conferences with Terez allow her the opportunity to encourage students to ponder some of the ways that the work in their portfolios might help students process the results of previous activities.

Recently, the students worked with prisms to learn more about refraction of light. Students also made diagrams and created a bulletin board showing their representation of atmospheric layers. Peers share what each has learned from evidence found in their portfolios. Finally, each group shares understandings in a portfolio presentation to the whole class.

Terez shares with us the newfound potential that portfolios offer her and her students. Student reflection becomes evident, as does individual student's learning over a period of time. The use of portfolios aids the learning process, engages students in creating the learning process, and allows for students' self-assessment. Students know what comes next; they revisit and continue to construct their own understandings when reviewing portfolios. Terez realizes that there is more to portfolios than assessment and she looks forward to using them to their full potential.

Portfolio Presentation

Groups of students use the work in their individual portfolios to create and then to answer challenging questions related to Sky and Light topics.

Discussion Questions

How has Terez' use of portfolios in science teaching and learning changed? In assessing individual learning

What do you consider to be the most promising uses of portfolios in science? The most problematic?

How would you go about building the use of portfolios into your science curriculum?

Case Studies in Science Education

Tom — Grade 5

Teacher Profile

Name	Tom
Experience	First-year teacher
Grade & Subject(s)	Grade 5; all subjects
Classroom	26 students; 10% special needs
Demographics	Suburban school in affluent town
Science Teaching	50-minute sessions; twice per week
Curriculum	Life, physical, and earth sciences; District specified
Other	Shares teaching responsibilities with Andy, another first-year teacher, who was initially brought into the classroom to assist with special needs students

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Module 1 - Introducing the Case

A cracker activity serves as the introduction for learning more about the human digestive system. Tom uses crackers to encourage students to consider the role of saliva and its enzymes in digesting food. Later, as a means of assessing students' understandings, Tom asks his students to write three paragraphs on digestion.

Tom is very aware of the diverse learners in his class and knows that traditional assessments serve some students very well, while not reflecting other students' understandings. This year Tom wants to experiment with alternative assessment techniques. By doing so, he hopes to make it possible for all students to represent successfully what they know, as well as to inform him and others of the understandings each student has built.

Cracker Activity

As a way of introducing students to the concept of digestion, students chew two crackers for five minutes before swallowing, observe what changes occur in the crackers, and then formulate a group hypothesis to explain what happened.

Discussion Questions

What teaching philosophies are evident in Tom's classroom?

What are your views on more traditional forms of assessment?

What assessment strategies might teachers use to help all students demonstrate their understandings?

Module 2 - Trying New Ideas

o show their understandings of electricity, Tom provides students with

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opportunities to represent what they have learned in several ways. Students create Cinquain poems, journal entries, Venn diagrams, and story boards. Each mode of assessment appeals to different types of learners. Tom discovers that these assessments also serve as learning experiences, making them an embedded part of teaching and learning.

Electricity Assessments

After exploring electricity and circuits, students use what they have learned to create poems, journal entries, Venn diagrams, and story boards to reflect their understandings.

Discussion Questions

What information can be derived from the assessment strategies Tom attempted?

What impact do you think alternative assessment has on the process of teaching? On the process of learning?

What additional forms of assessment might be useful for meeting the needs of diverse learners?

Module 3 - Reflecting and Building on Change

Tom discovers that different forms of assessment may be more or less

appropriate for different scientific concepts. Here, students use concept mapping to show what they know about electricity. Tom finds that concept mapping is particularly useful because it is open ended, allowing for the extent of students' understandings and depths of students' interpretations to be represented.

Tom adds to his growing conceptualization of assessment by suggesting that any assessment is only as beneficial as the degree to which we understand a student's prior knowledge. When teachers know this, then any assessment is a valuable tool for evaluating what students have learned over a finite period of time.

Tom wonders about asking students to choose for themselves which method of assessment they prefer and looks forward to learning more about alternative assessment in the years to come.

Electromagnet Activity

As they continue their study of electricity, pairs of students use a nail, copper wire, and a battery to make an electromagnet. Students test their electromagnets by using them to pick up paper clips.

Discussion Questions

How would you critique concept mapping as a way of detecting what students understand about a scientific concept?

What forms of assessment might help capture change in students' scientific understandings over time?

How would you solve the problem of linking alternative assessment to grading?