Hawker Brownlow EDUCATION

Caulfield Racecourse

Thinking & Learning Conference 2014

23–26 May MELBOURNE

Innovate! Educate! Inspire!

Anne Tweed

Saturday 24 May

Designing Effective Science & Maths Instruction in Secondary Classrooms

Session 2

ANNE TWEED

As a principal consultant, Dr Anne Tweed supports schools, districts and state departments with professional development activities that develop highly qualified teachers. Anne is a former president of the US National Science Teachers Association (NSTA) and spent 30 years teaching secondary school science, including environmental science, biology, chemistry, Earth science and marine science. She is now a Principal Consultant at McREL International. In addition to writing several books and articles, Anne also worked on the program planning team to revise the 2009 NAEP Framework for Science.

Published in Australia by

Hawker Brownlow EDUCATION

Hawker Brownlow Education
P.O. Box 580, Moorabbin, Victoria 3189, Australia
Phone: (03) 8558 2444 Fax: (03) 8558 2400
Toll Free Ph: 1800 334 603 Fax: 1800 150 445
Website: www.hbe.com.au
Email: orders@hbe.com.au

Printed in Australia

CODE: 11AT0202
0514

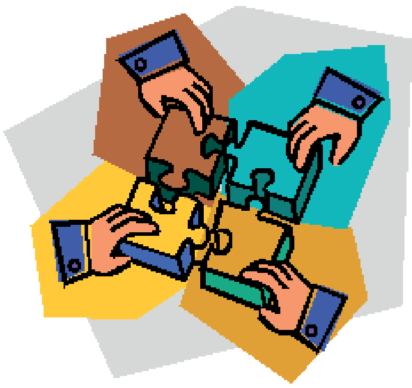
Exploring Effective Science and Maths Lessons

This section introduces recent research on the effectiveness of science and maths instruction in classrooms across the United States and in 6 countries including Australia. This information provides the foundation for the recommendations provided in the *Designing Effective Science Instruction* book as well as detailed definitions of quality and effectiveness.

In this section, you will focus on

- The research behind effective lessons
- Lesson strengths and weaknesses
- Setting goals
- Understanding how people learn

Warm-Up Activity: Jigsaw Puzzle



Discuss with a small group: In what ways is a jigsaw puzzle like a high-quality science or maths lesson?

The Quality of Science Lessons

The basis of many *DESI* recommendations comes from *Looking Inside the Classroom: A Study of K–12 Mathematics and Science Education in the United States* (Weiss, Pasley, Smith, Banilower & Heck, 2003), a report from Horizon Research, Inc., which provides many insights about the nature and quality of current K–12 science education. The TIMSS Video Study also aligns with this research.

Using a 1–5 scale, 1 being ineffective instruction and 5 being exemplary instruction, the study rated four key components of instruction:

- Lesson design
- Implementation
- Science content
- Classroom culture

What do you predict the research says about the quality of science and maths lessons?

Making Predictions

Record your prediction of what the research says about science lessons at the primary, middle, and high school levels. What percentage falls into each category?

How likely is a science lesson to be rated high, medium, or low in quality?			
	Primary Years 3-5	Secondary Years 6-8	Secondary Years 9-12
% High Quality			
% Medium Quality			
% Low Quality			

Discuss your predictions with others in your small group. How did your predictions differ from others?

Now, record the actual percentages for science classrooms in the Horizon Research study.

How likely is a mathematics/science lesson to be rated high, medium, or low in quality?			
	Primary Years 3-5	Secondary Years 6-8	Secondary years 9-12
% High Quality			
% Medium Quality			
% Low Quality			

Compare your group predictions with the actual numbers. What are your initial reactions?

Four Elements of Quality and Their Indicators

According to the Horizon Research study, four elements are essential to delivering high-quality maths and science instruction. Deficits in any one of these areas will decrease the efficacy of a science or maths lesson as a whole. Looking at these four areas and their indicators of quality can help you better reflect your own lessons.

- **Lesson design** consists of planning, instructional strategies, assigned roles, and resources used for the lesson.
- **Implementation** includes pacing, classroom management, teacher questioning, and teacher confidence.
- **Science or Math content** refers not only to the importance and grade-level appropriateness of the material being taught but also to student engagement in and sense-making of the content.
- **Classroom culture** includes the encouragement of active participation, quality of teacher-student and student-student interactions, and constructive feedback.

On the following page, read the indicators of quality for these four areas. Then, answer the questions to reflect on the quality of your lessons.

Indicators of Quality

Quality of Lesson Design	Quality of Lesson Implementation
• Resources available contribute to accomplishing the purpose of the instruction • Reflects careful planning and organization • Strategies and activities reflect attention to students' preparedness and prior experience • Strategies and activities reflect attention to issues of access, equity, and diversity • Incorporates tasks, roles, and interactions consistent with investigative science • Encourages collaboration among students • Provides adequate time and structure for sense-making • Provides adequate time and structure for wrap-up	• Teacher appears confident in ability to teach science • Teachers' classroom management enhances quality of lesson • Pace is appropriate for developmental levels/needs of students • Teacher is able to adjust instruction according to level of students' understanding • Instructional strategies are consistent with investigative science • Teacher's questioning enhances development of students' understanding/problem solving
Quality of Science Content	**Quality of Classroom Culture**
• Content is significant and worthwhile • Content information is accurate • Content is appropriate for developmental levels of students • Teacher displays understanding of concepts • Elements of abstraction are included when important • Appropriate connections are made to other areas • Students are intellectually engaged with important ideas • Subject is portrayed as dynamic body of knowledge • Degree of sense-making is appropriate for this lesson	• Climate of respect for students' ideas, questions, and contributions is evident • Active participation of all is encouraged and valued • Interactions reflect working relationship between teacher and students • Interactions reflect working relationships among students • Climate encourages students to generate ideas and questions • Intellectual rigor, constructive criticism, and challenging of ideas are evident

From Weiss, et al (2003) **Looking Inside The Classroom: A Study of K-12 Mathematics and Science Education in the United States.** Chapel Hill, NC: Horizon Research, Inc. Permission provided.

Engaging Students with the Content

One of the most important aspects of effective mathematics and science lessons is content that is both significant and worthwhile, and the majority of lessons do, in fact, include such content. However important content is not enough; high quality lessons invite students to interact purposefully with the content, and represent science and mathematics as dynamic bodies of knowledge generated and enriched by investigation. The following descriptions illustrate how lessons either effectively address, or fail to address, the need to engage students intellectually with the content. Identify the lessons as high, medium or low quality and provide a justification for your rating.

1. As a lesson on the skeletal system started, a life size skeleton, named Mr. Bones, was introduced to the 5^{th} grade class. The teacher talked about specific bones of the body, frequently capturing students' attention by telling stories and personal experiences: her husband's broken collar bone, actor Christopher Reeves' spinal cord injury, and her father's arthritis; students shared similar stories about the mailman with carpal tunnel syndrome and a mom with TMJ (temporomandibular joint disorder).

Rating: _____
Why?____
____

2. An 8th grade science lesson was designed to give the students a great deal of factual information on Newton's Third Law of Motion. The students copied notes from the blackboard for half of the lesson, and the next half of the lesson was spent with the teacher asking them to recall information from the notes.

Rating: _____
Why?____
____

3. The teacher in a human anatomy and physiology class began a lecture by drawing a diagram of a nerve receptor, connected by a nerve fiber to (eventually) the brain. He explained the concept of a threshold for a receptor, noting that stimuli could be either sub-threshold, threshold, or super-threshold, stressing that only after the threshold is reached does the receptor respond to the stimulus and send a signal to the brain. Using the hand as the point of reference, the teacher differentiated among different stimuli—touch, pressure, poke, punch, hammer, excruciating pain. He gave the example of an instance where if "punch" receptors were stimulated, the brain would not register "touch", only "punch." The students asked if it worked that way with taste, hearing, and sight.

Rating: _____
Why?____
____

Adapted from Looking Inside the Classroom, May 2003. Used with permission from Horizon Research, Inc.
Designing Effective Science Instruction, McREL 2004

Engaging Students with the Content

One of the most important aspects of effective mathematics lessons is content that is both significant and worthwhile, and the majority of lessons do, in fact, include such content. However important content is not enough; high quality lessons invite students to interact purposefully with the content, and represent science and mathematics as dynamic bodies of knowledge generated and enriched by investigation. The following descriptions illustrate how lessons either effectively address, or fail to address, the need to engage students intellectually with the content.

Identify the lessons as either high or low quality and provide a justification for your rating.

1. According to the observer, "success in this 6th grade mathematics class hinged on students learning algorithms. Students were to learn rules and procedures, not the concepts behind them. Although the teacher had told them at the beginning of the lesson that moving the decimal place in both the divisor and dividend the same number of places was essentially the same as multiplying them both by the same power of 10, the message given students throughout the lesson was, essentially, 'Just do it.' When students pushed the teacher for the reason they had to move the decimal, more than once the teacher responded: 'The divisor must be a whole number.'"

Rating: _____
Why?____
____

2. A 7th grade pre-algebra lesson began with the teacher introducing a new word problem. The purpose was to help reinforce the need for careful reading of problems, justification of strategies used and solutions presented, and the concept that there are multiple ways to approach solving a single problem. The students and teacher were engaged for three-quarters of this lesson in a whole class discussion about strategies used to solve this single word problem and presenting their solutions. The teacher stressed that there was "not a right way or a wrong way to solve a problem, but "many ways to get into an investigation." Throughout the lesson, the teacher made statements like "I think it would be a good idea to make sure you can verify your answer with others in your group." And "I need you to convince me it's the right answer."

Rating: _____
Why?____
____

Adapted from Looking Inside the Classroom, May 2003. Used with permission from Horizon Research, Inc. EL
McREL 2004

3. Observers noted that many lessons "just started." For example, a teacher began a 3rd grade lesson simply by having the students open their textbooks to the designated chapter, while she handed them a review worksheet. Similarly, a high school lesson began with the teacher distributing a packet of questions and saying, "All right now, these pages should be very easy if you've been paying attention in class. We talked about all this stuff."

Rating: _____
Why?____
____

4. In a high school Algebra I lesson, the teacher presented three line graphs showing data about two fictitious companies regarding productivity (intersecting lines), production cost (parallel lines), and sales (equivalent lines). He discussed graph with the class and then asked the class to vote for the company they would hire based on the graphs.

Rating: _____
Why?____
____

Adapted from Looking Inside the Classroom, May 2003. Used with permission from Horizon Research, Inc. EL
McREL 2004

Designing Effective Science Instruction

Identifying Important CONTENT	
Strategy 1: Identifying Big Ideas and Key Concepts. Identifying "big ideas," key concepts, knowledge and skills that describe what the students will understand. (This includes content from national, state and local standards and nanoscale science and technology)	
Strategy 2: Unburdening the Curriculum. Prune extraneous sub-topics, technical vocabulary and wasteful repetition.	
Strategy 3: Engaging Students with Content. Create essential questions that engage students with the content.	
Strategy 4: Identifying Preconceptions and Prior Knowledge. Identify common preconceptions and prior knowledge.	
Strategy 5: Developing Assessments: How Do You Know that They Learned? Develop assessments that correlate to the conceptual understanding and related knowledge and skills.	
Strategy 6: Sequencing the Learning Targets into a Progression. Clarify and sequence the learning activities to focus instruction on conceptual understanding	
Developing Student UNDERSTANDING	
Strategy 1: Engaging Students in Science Inquiry Engage students in science inquiry to develop understanding of science concepts and the nature of science.	
Strategy 2: Implementing Formative Assessments Make use of formative assessments to gather feedback on student progress toward understanding.	
Strategy 3: Addressing Preconceptions and Prior Knowledge Build on prior knowledge and address preconceptions.	
Strategy 4: Providing Wrap-Up and Sense-Making Opportunities Provide daily opportunities for wrap-up that support student sense-making.	
Strategy 5: Planning for Collaborative Science Discourse Develop student understanding through collaborative science discourse.	
Strategy 6: Providing Opportunities for Practice, Review, and Revision Teach concepts in depth by allowing students to continually refine their understanding through practice, review, and revision.	
Creating a Learning ENVIRONMENT	
Strategy 1. Believe All Students Can Learn. Show through your actions that you believe all students have the ability to learn.	
Strategy 2: Think Scientifically. Teach students to think scientifically.	
Strategy 3: Develop Positive Attitudes and Motivation. Develop positive student attitudes and motivation to learn science.	
Strategy 4: Provide Feedback. Give timely and criterion-referenced feedback.	
Strategy 5: Reinforce Progress and Effort. Keep students focused on learning by reinforcing progress and effort.	
Strategy 6: Teach Students to be Metacognitive. Involve students in thinking about their ideas and assessing their own progress.	

Characteristics of Effective Science Instruction		
1	Motivation	However well-designed the instruction, students are unlikely to learn if they do not have a desire to do so. • Instruction needs to "hook" students by addressing something they have wondered about, or can be induced to wonder about, possibly, in a real-world context.
2	Eliciting Students' Prior Knowledge	Research has shown convincingly that students do not come to school as empty vessels; rather, they come with ideas they have gleaned from books, TV, movies, and real-life experiences. • Instruction is most effective when it elicits students' initial ideas, provides them with opportunities to confront those ideas, helps them formulate new ideas based on the evidence, and encourages them to reflect upon how their ideas have evolved.
3	Intellectual Engagement with Relevant Phenomena	Lessons need to engage students in doing the intellectual work, and make sure that the intellectual work is focused on the learning goal. • When observing classroom instruction, it's helpful to ask yourself, "If I were a student in this class, what would I be thinking about?" • In order for classroom activities to be meaningful, they must be carefully designed to provide evidence for the targeted idea.
4	Use of Evidence to Critique Claims	An integral part of the scientific process is the collection and interpretation of data, which is then used to critique claims and see if they are supported by the evidence. • Students are less likely to revert to their prior incorrect ideas if they are familiar with the evidence that confronts those ideas and supports the scientific consensus. • Being scientifically literate requires understanding both scientific ideas and the nature of the scientific enterprise. Students should be encouraged to view science as a process by which knowledge is constructed, not as a collection of facts.
5	Sense-Making	Effective science instruction requires opportunities for students to make sense of the ideas with which they have been engaged: • Making connections between what they did in a lesson and what they were intended to learn and connecting the new ideas to knowledge that students already have, placing the lesson's learning goals in a larger scientific framework.

Adapted from Banilower, E., Cohen, K., Pasley, J. & Weiss, I. (2010). Effective science instruction: What does research tell us? Second edition. Portsmouth, NH: RMC Research Corporation, Center on Instruction

Improving Your Science or Maths Lessons

1. Use this cover sheet to analyze your unit or lesson, making brief notes of your thoughts. Start with "possible barriers", add "improvement strategies" as they come under your consideration.
2. When you revise your lessons, list specific corresponding changes in the third column, mark the place in the lesson where these changes can be found (e.g., footnotes, circled letters, page and section name)
3. Record what the students should be doing and there expected response in the final column.

Motivating Students			
Identify possible barriers	Identify improvement strategies	List specific changes made	Expected student response

Eliciting Students' Prior Knowledge			
Identify possible barriers	Identify improvement strategies	List specific changes made	Expected student response

Intellectually Engaging Students with Content			
Identify possible barriers	Identify improvement strategies	List specific changes made	Expected student response
Students Use Evidence to Make and Critique Claims			
Identify possible barriers	Identify improvement strategies	List specific changes made	Expected student response
Help Students Make Sense of Content			
Identify possible barriers	Identify improvement strategies	List specific changes made	Notation

CENTER ON INSTRUCTION

Elements of Effective Instruction

Workshop Handouts
and
Resources for Facilitators

Elements of Effective Science Instruction

Workshop Handouts and Resources for Facilitators

Center on Instruction
Science Strand
Horizon Research, Inc.

2008

CENTER ON INSTRUCTION

This publication was created for the Center on Instruction by Horizon Research, Inc.

The Center on Instruction is operated by RMC Research Corporation in partnership with the Florida Center for Reading Research at Florida State University; Horizon Research, Inc.; RG Research Group; the Texas Institute for Measurement, Evaluation, and Statistics at the University of Houston; and the Vaughn Gross Center for Reading and Language Arts at the University of Texas at Austin.

The Contents of this document were developed under cooperative agreement S283B050034 with the U.S. Department of Education. However, these contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government.

To download a copy of this document, visit www.centeroninstruction.org.

Vignette #1 – Sinking and Floating (hands-on)

A year four class has recently started a unit on sinking and floating. So far, students have brainstormed objects they have observed in their everyday lives that sink and float, and have shared their ideas as to why. Possible reasons they came up with include the mass of the object, how much air is in the object, and the size of the object. The purpose of this lesson is for students to figure out why objects sink or float.

The teacher had asked students to bring in small objects from home that they could use for this investigation. Students have brought in a wide variety of objects, including rulers (plastic and wood), coins, wooden blocks, Legos, golf tees, pencils, pens, balls (baseball, tennis ball, golf ball), and even plastic dolls. The teacher asks students to first write in their notebooks predictions of whether each object will sink or float in a tub of water. Next, they test their predictions. Students record the mass and size of each object and whether it floats or sinks in data tables they create in their science notebooks. The groups then place their data on chart paper, which they hang on the wall behind their tables. A sample data table is shown below:

Object	**Mass (g)**	**Shape**	**Sink or Float?**
Plastic ruler	42g	Long and skinny	Sink
Pencil eraser	13g	Small	Sink
Troll doll	243g	Medium	Float at first then sinks when water gets in
Penny	16g	Small	Sink
Charm bracelet	478g	Medium long and skinny	Sink
Wooden block	146 g	Small cube	Float
Toothpick	5 g	Small and pointy	Float

After the students have finished collecting data, the teacher leads a whole class discussion about their data and why things sink or float. For example:

Student 1: I noticed that when I placed the plastic cup on top of the water it floated, but if water gets inside the cup, it sinks.
Teacher: So what conclusion can you make from your evidence?
Student 1: I think air has something to do with it.
Teacher: Air has something to do with sinking or floating.
Student 2: I don’t think so.
Teacher: Tell us why you disagree.
Student 2: We talked the other day about how big heavy boats float, and big boats are filled up with lots of cargo and stuff so there’s less air in them but they still float. So I don’t think air has anything to do with it.
Teacher: Okay, so air doesn’t matter. Yes or No?
Some students in class nod their heads to indicate “Yes” and others shake their heads “No.”
Teacher: So what about the size of the boat?
Student 2: The boat is big and the cup is small, and both float.
Teacher: So is size an important factor in determining if things float or not?

Center on Instruction

Students: No.
Teacher: Okay, how about mass?
Student 3: I think that it doesn't have to do with mass.
Student 4: I don't think so…
Student 3: [Interrupting Student 4] Like a penny is not that heavy but it sinks.
Teacher: So you think that…
Student 5: Mass doesn't matter.
Teacher: …So you think mass is not a factor as to whether or not it sinks?
Student 3: The penny is light and it still sinks.
Teacher: So you're saying mass has nothing to do with it. We can throw mass right out the window.

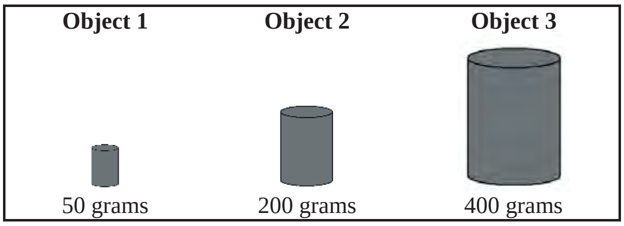
The lesson ends with the teacher summarizing the class discussion. The teacher tells students, "Today we investigated what factors determine whether an object sinks or floats. Some of you have already made some conclusions about why things sink and others are still thinking about your data. Tomorrow we'll try putting our objects in a different liquid – salt water – to see how that affects things."

Center on Instruction

Vignette #2 – Sinking and Floating (not hands-on)

A year four class is studying buoyancy. In a previous lesson, students were asked to brainstorm about what makes objects float or sink. Ideas volunteered by students included the mass of the object, how much air is in the object, and the size of the object.

The purpose of this lesson is for students to learn that mass alone does not determine whether an object sinks or floats. The teacher starts by saying, "At the beginning of this unit, you shared lots of factors that you think determine whether objects sink or float. Many of you thought the mass of the object was important. Let's find out whether the mass of an object determines whether an object sinks or floats. To start, I'll do a demonstration." The teacher shows students the three objects pictured below.



The teacher asks students to predict whether each object will float or sink. Almost all students think Object 1 will float and Object 3 will sink; students are divided as to whether Object 2 will float or sink. The teacher asks students for their reasons. One student shares, "Because heavy things sink and light things don't." Many students agree. The teacher places each object in a large tank of water, and the students observe, much to their surprise, that Object 1 sinks and Objects 2 and 3 float. A discussion follows:

Teacher: You seem surprised by the results of the demonstration. Tell me why.
Student 1: I thought if an object has a lot of mass, it sinks.
Student 2: Me, too. I don't understand why Object 1 sank, but Object 3, which was much heavier, floated.
Student 3: Maybe it was the way you placed the objects in the water that made them float or sink?
Teacher: Okay, I'll repeat the demonstration.

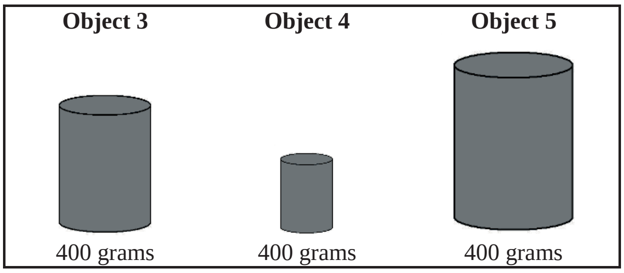
The teacher does the demonstration again, being sure to place each object in the water in the exact same way. The students observe the same results.

Teacher: So can we agree now that Objects 2 and 3 float, and Object 1 sinks?
Students: Yes.
Student 4: But that can't be right. I still think mass makes a difference. It must.
Teacher: Why do you think that?
Student 4: Rocks are really heavy, and you always see them at the bottom of rivers and creeks.
Teacher: Do you think those rocks are heavier or lighter than this 400 gram object?
Student 4: I think they are probably a lot heavier.

Center on Instruction

Teacher: Okay, so maybe we need to collect some more data. This next demonstration might help. *(Addressing the whole class)* Do you think all objects with a mass of 400 grams float? Let's test two more objects that have a mass of 400 grams.

The teacher shows the class two additional objects that are pictured below next to object 3:



Teacher: Do you think they will float? Why or why not?

Many students think that the new objects will float because their mass is the same as Object 3's. Some think that the new objects will sink because 400 grams is a lot of mass. The teacher places the objects in the water, and the class observes that object 4 sinks and object 5 floats.

Teacher: So what does this experiment tell us about mass and sinking and floating?
Student 5: Mass doesn't seem to matter.
Teacher: Does everyone agree? [Many students nod their heads in agreement.]
Teacher: Who can tell me why?
Student 6: The really heavy object in the first demonstration floated, but when you tested the other two objects that also were 400 grams, one floated and one sank.
Teacher: So what does that tell us?
Student 7: If mass was the reason why things float or sink, all of the 400 gram objects would have either sank or floated, but two floated and one sank.
Teacher: It sounds like we agree that mass alone does not determine whether an object floats or sinks. Can we think of some examples from real life that support this conclusion?
Student 8: At the swimming pool, we throw in coins and dive after them. They sink to the bottom of the pool, but they aren't very heavy.
Student 9: Boats. They are really heavy, much heavier than coins, and they float.
Teacher: If it isn't mass alone, do these demonstrations raise any new ideas about what factors might affect sinking and floating?
Student 10: Volume
Teacher: Why do you think volume might matter?
Student 10: In the first demonstration, the volumes of the objects were not all the same and we got different results—one object sank and two floated. So maybe the volume has something to do with it.

To close the lesson, the teacher says, "As a class, we are now in agreement that mass alone does not determine whether an object floats or sinks, but we need to consider in our upcoming lessons if volume is a factor that affects floating and sinking."

Center on Instruction

Vignette #3 – Conservation of Mass

An year 8 class is just beginning a unit on conservation of mass and energy. The purpose of this first lesson of the unit is for students to begin exploring the question of whether mass is conserved in a closed system. The teacher has put two scenarios on the chalkboard before class starts:

Scenario 1:
You have the following materials on a mass scale: one small beaker containing 250 ml of water; one beaker with 25 g of sugar; a wooden stirrer; and two cardboard cards, one covering each beaker. If you then mix the sugar into the water, stirring until it is completely dissolved, recover the beakers, and place all of the materials back on the scale, will the reading on the scale have increased, decreased, or stayed the same? Explain your thinking.

Scenario 2:
You have two beakers, each contains a different clear solution. Both beakers are on a mass scale, and both are covered by a piece of cardboard. You then pour the solution from one beaker into the other and replace the cardboard, and put both beakers back on the scale. Small white particles form and settle to the bottom of the beaker. Will the scale reading have increased, decreased, or stayed the same? Explain your thinking.

At the start of the class, the teacher asks students to discuss each scenario in their four-person teams, and to record their responses in their science notebooks. After the teams are finished, the teacher asks some teams to share their thinking, making sure to encourage students to share alternative ideas. During this portion of the lesson, the teacher responds to the teams' responses with neutral comments such as, "Interesting" or questions such as, "Why do you think that will happen?", taking care not to give students clues to the "correct" answer.

The teacher then tells the class that they will be doing these two experiments today in order to answer the following question: "In a closed system, do interactions cause the amount of mass to increase, decrease, or stay the same?" After the teacher gives a brief reminder of lab safety rules and of the "uncertainty" (measurement error) of the scale they will use, the students gather the materials needed for the experiments and begin data collection. The teacher provides them with a sample data table to use, which they copy into their notebooks:

	Dissolving Sugar in Water (Scenario 1)	**Mixing Chemicals (Scenario 2)**
End Mass	___________ g	___________ g
Start Mass	___________ g	___________ g
Change in Mass	___________ g	___________ g

Center on Instruction

Class Average Change in Mass	___________ g	___________ g
Uncertainty in Mass	___________ g	___________ g

While the students are collecting their data, the teacher circulates around the room, providing assistance when necessary and making sure students are making careful measurements. After the students complete data collection, the teacher asks the teams to consider the following question: "Taking into account the uncertainty in mass, does the mass increase, decrease, or stay the same?" Although some teams found a very small change in mass, the entire class agrees that the change is within the uncertainty of the scale.

The teacher then has students individually respond to two questions in their notebooks:

1. What do the data in this activity indicate about mass in a closed system? Write your reasoning and include evidence from the activity.

2. How do the results in this activity compare with your predictions?

As students are working, the teacher circulates, checking students' responses. After all students have finished writing, the teacher leads a class discussion around these questions to make sure the class agrees on the conclusion that mass is conserved in a closed system, even when there are interactions among the objects in the system, and that they agree which data support this conclusion.

Characteristics of Effective Instruction
Conservation of Mass: Individual Record Sheet

Evidence of "Motivation"
Evidence of "Eliciting Prior Ideas"

Center on Instruction

Evidence of “Intellectual Engagement”
Evidence of “Use of Evidence”
Evidence of “Sense-Making”

Center on Instruction

Vignette #4 – Subduction

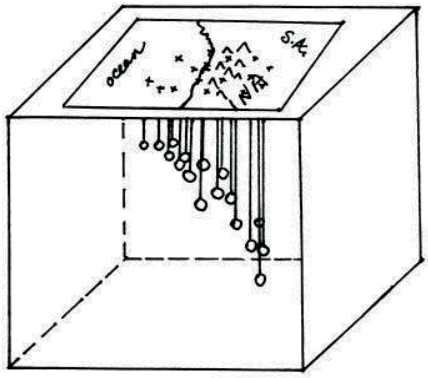
This lesson occurs toward the beginning of a unit on plate tectonics. The year 9 students have been going through a series of lessons to help build an understanding that Earth consists of plates and that plate movement explains several phenomena on Earth (e.g., mountain formation, earthquakes, volcanoes). The purpose of this particular lesson is for students to understand that subduction, where one plate moves beneath another plate, is one type of interaction that can occur at plate boundaries.

The teacher begins the lesson by reminding students they have been talking about Earth's plates, and that the topic is very important as the end-of-course assessment has several items on plate tectonics. The teacher asks students to respond to the following questions as their "warm-up" activity: *What do you think happens at plate boundaries? How do the plates interact?*

After students have finished writing responses in their notebooks, the teacher calls on some students to share their thoughts:
Teacher: So what happens at plate boundaries?
Student 1: Plates move, and we can see them moving at their edges.
Teacher: Can we really "see" them? No, but we have evidence that they move. What is some evidence that we've examined to support the idea that plates move?
Student 2: Hot spots and the pattern of the island chains they form.
Student 3: Earthquakes.
Teacher: So, how is an earthquake related to plates?
Student 3: There's a fault there, which I think is near a plate edge or something.
Teacher: Interesting. We've talked about earthquakes being evidence that rock is breaking and moving and are common at plate boundaries. We've also talked about how hot spots, if we assume they are stationary, form chains of islands. If the island chain is not near a plate boundary, the pattern of progressively older islands in the chain suggests that the plate is moving. So, can we accept these phenomena as evidence plates do move?
Students nod in agreement.
Teacher: Alright, now we haven't talked yet about the ways in which plates can move. How can they move?
Student 1: Plates slide back and forth, like side to side.
Teacher: Are there other ways or do plates only move one way?
Student 4: They can bump into each other.
Student 5: Yeah, they can push together.
Teacher: Any other ideas? [Students did not offer any more ideas.]

The teacher tells the class that today, they are going to use real earthquake data from a region in South America to see if they can learn more about ways plates move and interact with each other. The teacher places on each student table a model consisting of an open box with a map of the west coast of South America taped on top and strings of varying lengths with beads on their ends hanging inside the box. (A picture of the model follows.) The teacher explains that the map on the top of the box represents the surface of Earth and the open side of the box represents their view beneath the surface of Earth.

Center on Instruction



Each student also receives a table with a list of the locations of earthquake foci in this particular region, including latitude, longitude, and depth measurements from 1993 to 2004. In the model, the latitude and longitude are marked on the map on top of the box, and the depth of the earthquake foci are represented by the length of the string under each mark on the map. The bead hanging from the string represents the location of the focus of each earthquake.

The teacher gives students a few minutes to examine the model and data table, then leads a discussion about the data represented in the model. The conversation includes:

Teacher: What do you notice about the depth of the foci of the earthquakes as you go further inland from the coast of South America?
Student 6: Earthquakes are happening at deeper and deeper places.
Teacher: Correct, the earthquakes are deeper as you move inland. Let's look at our world map of Earth's plates. What does it show us on the west coast of South America?
Students: That there are two plates that meet along the west coast of South America.
Teacher: Yes, one is the South American plate and one is the Nazca plate. Based on the data we looked at today and our model, we are able to make an inference about the interaction of these two plates. According to the data, it looks like one plate is moving beneath another plate. In this case, the Nazca plate is moving beneath the South American plate. This type of plate movement is called subduction.
The teacher writes the term on the board, and students record it in their notebooks.
Teacher: So why would scientists come to this conclusion? What is some evidence that one plate is moving under the other? [Pause] Write down your thoughts in your journal.

Students take a few minutes to write. Once most are finished, the teacher resumes his discussion:
Teacher: Reflecting on the conversation we had earlier, if these two plates were just sliding back and forth, side to side [the teacher models with his hands], where on the plates would we detect earthquakes?
Student 7: On both sides of the fault.
Teacher: Good. And if plates are moving toward each other [the teacher models with his hands] where on the plates would we see evidence of this type of movement?
Student 8: It's the same. You'd have earthquakes on both sides of the plates.

Center on Instruction

Teacher: Good. So according to your model, what appears to be happening at this plate boundary?
Student 9: The plate is bending down.
Teacher: Can you say more about that idea? Use your evidence.
Student 9: It looks like one plate is going down. My evidence is the earthquakes go in a pattern deeper in the Earth.
Teacher: Yes, that's exactly what scientists noticed.

The teacher then has students record that one piece of evidence for subduction is the pattern of progressively deeper earthquakes along a plate boundary, indicating that rock is breaking and moving.

The teacher then says, "Earlier we were talking about ways the plates can move relative to one another. We can now agree that a plate can move beneath another plate. What do you think happens to the size of Earth if plate material moves beneath another plate? That's your homework for tonight; record in your journals what you think happens to the size of Earth when it subducts. We'll talk about it in class tomorrow."

Characteristics of Effective Instruction
Subduction: Individual Record Sheet

Evidence of "Motivation"
Evidence of "Eliciting Prior Ideas"

Center on Instruction

Evidence of "Intellectual Engagement"
Evidence of "Use of Evidence"
Evidence of "Sense-Making"

Center on Instruction

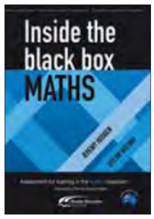
RELATED RESOURCES

Available from Hawker Brownlow Education

Qty	Code	Title	Price
	111001	Classroom Instruction That Works, 2nd Edition	$29.95
	NST0782	Designing Effective Science Instruction: What Works In Science Classrooms	$39.95
	NST0881	Hard-to-Teach Biology Concepts	$37.95
	GLA1321	Inside the Black Box: Maths	$10.95
	GLA1338	Inside the Black Box: Science	$10.95
	112012	Using Technology with Classroom Instruction That Works, 2nd Edition	$35.95
	102271	What Works In Schools: Translating Research Into Action	$27.95
		Total (plus freight) $	

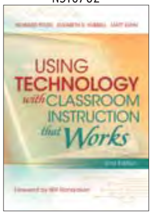
NST0782

NST0881

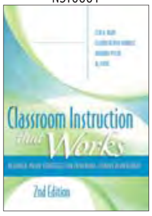


GLA1321

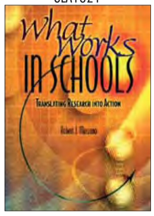
GLA1338



112012



111001



102271

Attention .... Order Number ....

Name of School..

Address...

.... State ....P/Code ....

Country ....

Email:..

☐ Yes, I would like to receive emails from Hawker Brownlow Education about future workshops, conferences and the latest publications.

Terms of Trade

- Prices are quoted in Australian dollars ($AUD) and include GST
- All prices are subject to change without notice.
- For New Zealand customers, at the time of invoice, we will convert the amount into New Zealand dollars ($NZD) so that you can pay by cheque or credit card in New Zealand dollars ($NZD).
- Full money-back guarantee.
- We do realise it is difficult to order sight unseen. To assist you in your selection, please visit our website <www.hbe.com.au>. Go to 'Browse Books' and most titles will give you the option to view the first few pages of the book. Click 'View Contents' on your selected book page.
- We will supply our books on approval, and if they do not suit your requirements we will accept undamaged returns for full credit or refund. Posters are for firm sale only and will not be sent on approval. Please be aware that delivery and return postage is the responsibility of the customer.
- Freight costs are determined at Australia Post rates, with a minimum delivery charge of $9.50 within Australia and $15.00 for New Zealand for each order.
- Please provide your street address for delivery purposes.

To place an order, request a catalogue or find out more about our resources:

Call
1800 334 603
(03) 8558 2444

Fax
1800 150 445
(03) 8558 2400

Online
www.hbe.com.au

Mail
Hawker Brownlow Education
PO Box 580,
Moorabbin, VIC 3189

Do you want to know all about the latest professional development events in your area? Be the first to find out about new releases from world-renowned and local authors with the HBE e-newsletter! Upcoming titles will feature authentic assessment and digital media, along with a strong focus on success in mathematics and literacy. Sign up to our FREE e-newsletter at www.hbe.com.au.

Online 'On Account' ordering now available!
If you have a pre-existing account with Hawker Brownlow Education, you can now order online and pay using that account.