Inquiry-Based Science Education

Global Science Education

Professor Ali Eftekhari
Series Editor

Learning about the scientific education systems in the global context is of utmost importance now for two reasons. Firstly, the academic community is now international. It is no longer limited to top universities, as the mobility of staff and students is very common even in remote places. Secondly, education systems need to continually evolve in order to cope with the market demand. Contrary to the past when the pioneering countries were the most innovative ones, now emerging economies are more eager to push the boundaries of innovative education. Here, an overall picture of the whole field is provided. Moreover, the entire collection is indeed an encyclopaedia of science education and can be used as a resource for global education.

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Inquiry-Based Science Education

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INTRODUCTION

This chapter provides an introduction to inquiry teaching in science, models for teaching inquiry, and approaches to evaluating the inquiry process. In recent years, emphasis has been on teaching science using an inquiry approach where students are actively involved in scientific investigations that challenge their curiosity, encourage them to ask questions, explore possible solutions to problems, use evidence to explain phenomena, elaborate on possible effects, evaluate findings, and predict potential outcomes if different variables are changed. This chapter also presents examples of how students are cognitively challenged to make sense of the phenomena under investigation, develop evidence-based explanations, and communicate their ideas and understandings in discipline-specific language as to why solutions to problems work and others do not.

BACKGROUND

Over the last two decades, emphasis has been on teaching science through inquiry. Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities to scrutinise a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively, and in so doing, learn to reconcile their developing understandings with previous knowledge and experience. Inquiry has many potential benefits. When students are involved in inquiry-based science, they are *doing science* where they are learning the processes communities of scientists employ to investigate phenomena. In so doing, they learn to explore possible solutions, develop explanations for the topic under investigation, elaborate on concepts and processes, and evaluate or assess their understandings in the light of the evidence available to them. This approach to teaching relies on teachers recognising the importance of presenting problems to students that will challenge their current conceptual understandings so they are forced to reconcile anomalous thinking and construct new conceptual understandings.

Cultivating students' scientific habits of mind, developing their capabilities to engage in scientific inquiry, and teaching them how to reason in the scientific context is one of the principal goals of science education (National Research Council, 2012, p. 41). In fact, the essential elements in any science education programme must include: (a) the development of conceptual understanding; (b) the improvement of cognitive reasoning; (c) the improvement of students' understanding of the epistemic nature of science; and (d) the affordance of effective experiences that are both positive and engaging (Osborne, 2006). Furthermore, this needs to occur within the context of social practices and values that both promote and sustain the scientific enterprise and lead to the production of reliable knowledge.

When students have opportunities to engage with their peers in collaborative scientific inquiries, they learn to ask questions about different phenomena, plan investigations, use a variety of tools and artefacts to collect and analyse data, and use evidence to develop claims and propose possible explanations for the phenomena they have observed (Bell et al., 2010; Llewellyn, 2014). In inquiry-based science, students not only learn the relevant content but also learn the discipline-specific reasoning skills and practices by collaboratively engaging in authentic problems or questions with their peers. In so doing, students are cognitively challenged to make sense of the phenomena under investigation, develop explanations that are based on evidence, and communicate their findings in discipline-specific language as to why certain solutions to a problem work and others do not.

When you have finished this chapter, you will know:

- What inquiry-based science is.
- How inquiry-based science challenges students' thinking.
- Strategies teachers can use to promote inquiry-based science in their classrooms.
- Challenges teachers face when implementing inquiry-based science in their classrooms.

INQUIRY-BASED SCIENCE

Inquiry-based science is an investigative approach to teaching and learning where students are provided with opportunities to investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, think creatively, and use their intuition. The inquiry process is complex as it involves students reconciling their current understandings with both the evidence obtained from an inquiry and the ability to communicate their newly acquired knowledge in a way that will be accepted as well-reasoned and logical. Such a process is challenging, requiring teachers to play an active role in helping students learn the steps in the inquiry process.

Scientific inquiry recognises the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. It also refers to "the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (National Science Teachers Association, 2004, p. 1). When students have opportunities to engage in scientific inquiry, they learn to use their ideas and, in so doing, deepen their conceptual understanding of scientific content as well as their understanding of how to do science. "This science-as-practice perspective brings together content knowledge and process skills in a manner that highlights their interconnected nature" (Harris & Rooks, 2010, p. 229), facilitating student engagement with complex science ideas and participation in scientific activities. In effect, students gradually learn to understand the practices that scientists engage in when confronting various scientific problems (Herrenkohl et al., 2011).

Inquiry is the process of investigating a problem issue that requires critical thinking, observing, asking questions, testing out ideas and hypotheses, and engaging in collaborative discussions to communicate scientific knowledge and develop explanations or solutions on the topic under discussion (Lee et al., 2004; Metz, 2008). While children often demonstrate a natural curiosity about the world in which they live, research indicates that they rarely ask questions about what they have seen and heard. Helping students to understand the inquiry process where they learn to ask questions about phenomena that challenge their current understandings, propose possible explanations for what they see, and reconcile understandings with their current knowledge to create new knowledge and understandings takes a concerted effort on the part of the teacher. While there are many approaches to teaching students how to engage in inquiry, Figure 1.1 represents generally agreed steps in the process.

Inquiry learning is seen as critically important to helping students engage in science, yet teachers continue to struggle with what inquiry should look like and how it should be taught. Zuckerman et al. (1998) identified three factors that they considered crucial for teaching inquiry science to primary and middle years students. These factors are

1. Arousing students' imagination by presenting new and awe-inspiring phenomena that are already within students' current level of development so the child has the capacity to recognise the new

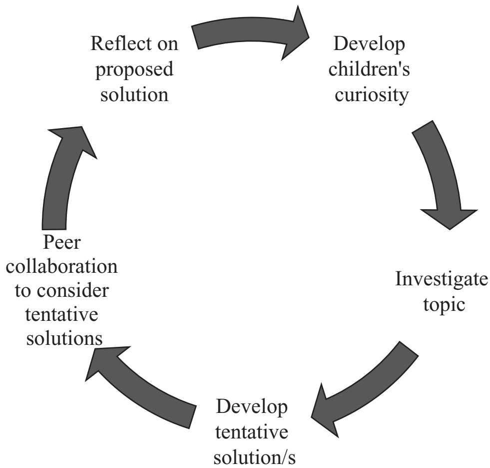


FIGURE 1.1 Steps in the inquiry process.

elements in the phenomena and to connect these new elements to the context and structure of existing background knowledge and experience.

2. Teachers need to provide opportunities for students to work with others to investigate, discuss, and resolve challenging problems.
3. Students need to be encouraged to participate in asking questions to help them test out their ideas and eventually verify their hypotheses.

The promotion of inquiry is highly dependent on the teachers' efforts to guide and scaffold students' learning as they engage in the inquiry process, so they understand how to think as they participate in tasks, as well as acquire the procedural knowledge of how to complete these tasks (Duschl & Duncan, 2009; Veermans et al., 2005). This involves challenging children's thinking and problem-solving by making explicit the types of thinking they need to demonstrate. When this occurs, Gillies and Boyle (2006) found that children, in turn, are more focused and explicit in the types of responses they provide and the help they give to each other.

Given that inquiry usually involves collaborative discussions, students need to know how to cooperate with peers so they listen to what others have to say, share ideas and information, clarify misconceptions, generate new understandings, and critically reflect on what they have learned and what they still need to learn. In fact, when this happens in science classrooms, Ford and Forman (2015) argue that students engage in a process of dialogical discourse that encourages them to collaboratively construct and critique different ideas and points of view and, in so doing, they begin to learn how to function as a scientific community. This give and take in discussions, Ford and Forman believe, is essential if productive scientific talk is to occur. Moreover, it is this dialogical discourse that, in turn, supports changes to students' reasoning and scientific habits of mind or way of reasoning that promotes problem-solving, insightfulness, perseverance, creativity, and craftmanship (Costa & Kallick, 2000).

USING INQUIRY-BASED SCIENCE TO CHALLENGE THINKING

Inquiry-based science challenges students' thinking by engaging them in investigating scientifically orientated questions where they learn to prioritise evidence, evaluate explanations in the light of alternative explanations, and communicate and justify their decisions in language that is specific to science. However, in a review of 225 studies between 1972 and 2011, Howe and Abedin (2013) found that classroom dialogue is dominated by teacher–student initiation-response feedback (I-R-F) (e.g., Teacher: Who was the first man on the moon? Student: Neil Armstrong. T: Yes, that's right), which tends to only require minimal responses with no elaboration. Unfortunately, research indicates that students rarely engage in classroom-based discourse where they ask question, discuss issues, or provide reasons for the positions they have taken. On the other hand, Mercer and Sams (2006) found that when students were taught how to use language as a tool for thinking and reasoning, they were able to use talk to think and reason more effectively. In a similar vein, Gillies and Baffour (2017) found that when teachers spent time interrogating students' understandings and scaffolding and challenging their thinking, the students, in turn, were more attentive and used more sophisticated scientific language to explain the phenomena they were investigating than students in classrooms where teachers did not emphasise these practices.

There is no doubt that teachers play a key role in inducting students into ways of thinking and reasoning by making explicit how to express ideas, seek help, challenge different propositions, and reason in a well-argued and cogent manner. While research clearly indicates that when teachers make use of these dialogic strategies, students' participation in class and their educational achievements are likely to benefit (Mercer & Dawes, 2014), many teachers are still reluctant to embrace these strategies, preferring to utilise a transmission model of teaching where the teacher controls the channels of communication and the students remain as passive recipients.

One instructional approach that has been used successfully to teach inquiry science that challenges children's thinking and learning is the 5Es Instructional Model (Bybee, 2014). This model of teaching is research based and highlights the importance of cooperative learning where students work together in small groups to resolve problems. It also recognises the importance of students engaging in activities that challenge their current conceptions (or misconceptions) with opportunities provided to enable them to restructure their ideas and abilities.

The 5Es Instructional Model consists of five phases that Bybee (2014) believes is iterative with teachers recycling through this approach as needed. The five phases are Engagement, Exploration, Explanation, Elaboration, and Evaluation.

1. **Engagement.** The goal of this phase is to capture the students' attention and curiosity through the presentation of a novel event, situation, demonstration, or problem that involves the content and the abilities the lesson is designed to teach. For example, if students were about to embark on learning about earthquakes, the presentation of video on a tsunami and the population affected would be an example of an activity designed to engage students' attention and curiosity. Follow-up questioning by the teacher will help to challenge students' thinking as they consider the implications of such an event. For example,
   - *What do you think may be the impact of this event on people's lives?*
   - What sort of planning do you think people may need to do if they live in areas that are prone to earthquakes?

The purpose of this phase is to attract students' attention and interest in the topic with the intention of motivating them to explore or investigate the topic in more depth. Activities associated with this phase may include developing a Think, Want, Learnt, How (TWLH) chart where the students identify what they currently know about earthquakes, what they want to learn, what they have learned, and how they know.

TWLH Chart

WHAT WE THINK WE KNOW	*WHAT WE WANT TO LEARN*	*WHAT WE LEARNED*	*HOW WE KNOW*

The TWLH chart is used to assess students' current understandings and beliefs about the topic with the intention of helping them to identify what they still want to learn. The process is very much a guided inquiry as the teacher probes the students' knowledge and understanding and gauges their abilities to reconcile new and challenging information into their cognitive schema. This phase also provides opportunities for the teacher to informally uncover any misconceptions that students have in order to plan activities and experiences to help students explore the topic in more depth.

2. **Exploration.** This next phase focuses on providing opportunities for students to explore the topic in more depth. This may include through electronic searches, group discussion, a visit from a scientist who can elaborate on the topic, or a field trip to gather information. Consequently, students would be expected to be able to describe the difference between terms associated with earthquakes, discuss the use of different scales for measuring earthquakes, and analyse different numerical and factual information. These activities would occur in the context of group discussions where students share their information and findings, read and analyse factual information together, and identify questions that need to be resolved.

Questions such as the following may be posed by the teacher to help students explore the topic in more depth:

- *What happens when an earthquake occurs?* Describe what you have learned from your exploration of this topic.
- What instruments are used to measure the strength of an earthquake?
- What is the difference between the Richter and the Modified Mercalli scales? Describe the advantages and disadvantages of each.
- What happens to the tectonic plates when they are subject to different stresses? Describe the effects.

3. **Explanation.** The scientific explanation for the phenomena under investigation is actively pursued during this phase with the teacher directing students' attention to key parts of the previous phase while "pressing" students for their explanations. Building on students' explanations and experiences, the teacher introduces key concepts and technological terms, including the relevant scientific vocabulary and practices that help to make the explanations clear. It is important that the students are introduced to activities that are challenging yet achievable with scaffolding by the teacher if needed. Activities where students learn to construct multimodal explanations drawing

on a range of representations (e.g., tables, pictures, oral presentations, videos, and models) are undertaken during this phase. Specific examples may include:

(a) Using written language and models to demonstrate their understanding of earthquakes and tectonic plates.
(b) Using scientific language to describe three types of tectonic plate movements and their effects on the earth's crust.
(c) Constructing a portfolio on a topic that is designed to provide an ongoing record of work that students have attempted or have completed. Portfolios provide insights into students' abilities to communicate scientifically, demonstrate scientific reasoning, and make connections between different concepts and relationships. They also enable students to reflect on the progress they have made and what they still need to do if they wish to achieve. This activity can be conducted in conjunction with the class teacher when students discuss personal learning goals or as part of a group activity where the group identify what they want to achieve.

During this phase, it is critically important that the teacher asks thought-provoking questions to help students think deeply about the topic they are investigating. The following are examples of such questions:

- *Explain why or how….?*
- What is the difference between … and …?
  What do you think could happen if …?
- What do you think causes … and why?
- What is the evidence that supports this statement?

4. **Elaboration.** This phase builds on the previous phase so students are encouraged to elaborate on their conceptions using additional information and understandings. During this phase, the teacher actively challenges students' current conceptions and skills by providing additional experiences that will help them to develop new insights and broader understandings of the topic. For example, students may be discussing how movement of the earth's tectonic plates can create earthquakes that can occur on land or in water. The teacher may build on these understandings by challenging the students to elaborate on how tectonic plates move

(e.g., convergent, divergent, or transform) and the different effects they generate. In so doing, the teacher encourages more in-depth analysis and elaboration on the phenomena. Students, in turn, can elaborate on their current conceptions through writing reports or producing portfolios, participating in debates that challenge current conventions, or utilising diagrammatic and graphic modes to present information that provides additional insights on the topic at hand.

Additional activities may include:

(a) Constructing a seismometer to illustrate how data on seismic waves are collected. Students work in small groups to construct the seismometer and demonstrate how data can be collected from it.
(b) Interview a seismologist to determine what this scientist does, how information is collected and interpreted, and how that information is communicated to the wider community.
(c) Work in small groups to build models to withstand weak and strong simulated earthquake movements and elaborate on the advantage and disadvantage of each. Attention should be directed at ease of construction, cost of materials, aesthetic appeal, and impact on the population affected.

Questions that could be used to challenge and scaffold students' elaborations include:

- *Perhaps you can provide further information on how and when seismic data are collected by seismologists and what they do with these data?*
- Many people in the population would find it difficult to interpret seismograms so I wonder if there may be other ways in which this information can be communicated?
- Perhaps you can elaborate further on how seismograms can be used to help people understand the consequences of living in earthquake-prone regions?

5. **Evaluation.** This final phase provides teachers and students with the opportunity to review the progress the students have made in developing different scientific understandings through both informal and formal assessments. Informal assessments can include the collection

> of various artefacts (e.g., journals, portfolios, models, exhibitions of performance) that demonstrate different conceptual understandings, while formal assessments may include responses to specific tests designed to ascertain students' conceptual understandings of the topic.

During this phase, teachers need to provide opportunities for students to reflect on their progress. This may be done in a one-on-one conference where the teacher interviews each student to ascertain what they have learned and what they may still be struggling to understand. The language students use during this case conference is just one way of gauging how the students are using different scientific terms and language in response to questions asked.

Another approach to encouraging students to reflect on their learning involves using the following Know, Learned, and Questions raised (KLQ) chart. This chart acts as an organiser to help students discuss their responses to these probes. This activity can be undertaken individually or as part of a small-group activity. The advantage of this type of activity is that the chart provides a structure that enables teachers to promote thinking, reflection, and metacognitive processes in a coherent fashion by asking students to recall what they know and have learned as well as think metacognitively by reflecting on what questions remain unanswered. These are thinking processes that successful learners demonstrate.

KNOW	*LEARNED*	*QUESTIONS RAISED*

Questions that can be asked during this phase may include the following five types of questions that King (1997) identified as part of a sequence of questions to promote higher-level thinking:

- "Describe … in your own words" (Review questions)
- "Tell me more about …" (Probing questions)
- "Have you thought about …?" (Hint questions)
- "What is the difference between … and …?" (Intelligent-thinking questions)
- "Have I covered all the points I need to?" (Self-monitoring questions)

STRATEGIES PROMOTING INQUIRY-BASED SCIENCE

"Scientific inquiry requires the use of evidence, logic, and imagination in developing explanations about the natural world" (Newman et al., 2004, p. 258). In inquiry-based science, students work together in cooperative small groups to investigate topics, share information that they have found, and discuss and evaluate different explanations that may explain the phenomena. This process is iterative until they can communicate and justify their explanations in the context of the investigation they are undertaking.

Cooperative Learning Activities

Successful cooperative learning activities involve students working together, listening to each other's ideas, trying to understand different perspectives, suggesting alternative explanations for the phenomena, and working together constructively to accept responsibility for completing their part of the task while assisting others to do likewise. When this happens, Ford and Forman (2015) argue that students engage in a process of dialogical discourse that encourages them to cooperatively construct and critique different ideas and perspectives and, in so doing, they begin to learn how to function as a scientific community. Ford and Forman maintain that this type of interaction is essential if productive scientific talk is to occur. Moreover, it is this dialogical discourse that, in turn, supports changes to students' conceptual understandings and reasoning and scientific habits of mind.

Strategies to help students learn to work cooperatively together include:

1. **Brainstorm with a Peer.** Have students work with the student beside them to brainstorm some ideas from the lesson. Jot down six ideas. Allow 2 minutes for this activity. The teacher then calls on different dyads to report what they discussed. The advantage of this type of activity is that it helps students to learn to listen to others and consider their ideas.
2. **Paired Activity.** Students interview each other about their favourite DVD, sport, activity, book, and so on. The students spend 2 minutes on this activity. The teacher then calls on specific dyads to introduce each student to the class. As a follow up to this activity, it is important for the teacher to discuss with the class whether the students now have a better understanding of the person who was being

introduced and what questions might need to be asked to provide clearer information. The advantage of this activity is that it makes students aware of other students' interests and, because they will be required to introduce the other student to others, they have to actively listen to what is said.

3. **Listen and Recall.** Students work in pairs on a topic and jot down the main ideas. One adopts the role of the listener while the other recalls the information they have learned. The listener tries to ask questions to help clarify issues or assist the other recall what was learned. Questions such as the following are used to probe and clarify issues:
   - What do you mean by …?
   - Can you tell me more about …?
   - What would happen if …?

After 5 minutes, the students change roles and the process of interrogating the topic begins again. As students learn to ask more questions to help clarify the issues they are discussing, their questions become more detailed and the responses more elaborated. Moreover, King (1999) found that by encouraging the listener to ask more thinking questions, the recaller is more likely to respond with explanations and elaborations or the types of responses that are known to promote learning. Eventually, as the students learn to think more deeply about the information they are discussing, they learn to ask more metacognitive questions or questions that demonstrate how they are thinking about the topic.

4. **2-Minute Review.** The teacher stops at any time during the lesson and gives students (working in pairs) 2 minutes to recall aspects of the lesson. Students are then called on by the teacher to discuss what their dyad identified. The advantage of this review is that once students get used to this routine, it helps them to stay "tuned in" to what the lesson is about. As most children will not readily be able to recall all aspects of the lesson, they will rely on their peer to assist with this task, thereby demonstrating interdependence with "two heads better than one"; a key element of successful cooperative learning (Gillies, 2007).
5. **Paired-Questioning.** Students read a passage together and then ask each other a set of specific questions to help clarify their understanding of it. It may be necessary to cue students' questioning by giving them a set of question stems to guide their questioning. For example:

- What is the main idea of ...?
- Explain why ...?
- Explain how ...?
- How are … and … similar?
- What is the difference between … and …?
- How does this relate to what I've learned before?
- What did you like about …?

The advantage of this activity is that students learn how to ask progressively more difficult questions as they seek to clarify their understandings of the information.

6. **Think-Pair-Share.**

   Students work in pairs on a topic. Pairs then join another pair to form a group of four. One pair shares the information and ideas they have with the other pair, then the other pair shares their information and ideas. Students are then required to develop a common list of points or ideas. Students number themselves from 1 to 4 as the teacher asks a number (i.e., student) from each group to discuss an idea their group identified as important and why they chose this idea.

   There are two advantages to this approach:
   1. Students need to listen to what the group members have been discussing if they are to present an idea the group have discussed.
   2. The student who responds presents an idea the group have discussed rather than an individual's idea. This helps to reduce anxiety during the feedback session.

Other strategies that assist cooperation include:

Group size
Students work best in groups of two, three, or four members, simply because it is easy to hear and see what the group is doing. In larger groups, it is easier for students to passively participate as others may dominate the discussion, the roles, and the resources with little regard for less active students.

Group composition
The composition of the group is also important as research indicates that students generally work better when

- Groups are mixed in ability (high, medium, and low), although teachers need to be careful to ensure that low-ability students are not too overwhelmed by the group.
- Mixed gender.
- Status is provided to low-status students with an emphasis on the strengths a particular student brings to a group.

Type of task
There are a range of tasks that students can undertake to help them learn how to work cooperatively together. These include simple and complex tasks.

Simple tasks involve:

- Brainstorming ideas
- Recalling basic information
- Jotting down main ideas on a topic

Complex tasks will require the students to problem-solve together. This may involve:

- Identifying possible solutions to a problem and justifying answers.
- Identifying possible solutions to a problem, including both the positive and negative consequences, choosing the best solution, justifying the answer, and then developing a logo, text message, or advertisement that clarifies this choice and justification.
- Identifying a list of questions that could be asked to help clarify the problem.

Complex tasks that challenge thinking are constructed so there is no right answer, requiring students to discuss how to proceed. This type of task is usually completed in small groups where students are expected to work together to contribute ideas, discuss the perspectives and ideas of others, and evaluate possible solutions in the light of the information presented.

Students engaged in challenging tasks are also encouraged to evaluate the process the group employed in working towards a solution and the outcomes achieved. This can be achieved by asking students to reflect on:

what we have achieved;
what we still need to achieve; and
how might we do this.

Individual Reflection Activity

SKILLS	*THIS IS HOW I RATE MYSELF*		
I used positive statements to encourage my group members.	Always	Sometimes	Never
I contributed my ideas and information.	Always	Sometimes	Never
I asked others for their ideas and information.	Always	Sometimes	Never
I helped others in my group learn.	Always	Sometimes	Never
I helped the group organise and write up the group's ideas and information.	Always	Sometimes	Never
I stayed on task and followed my group role.	Always	Sometimes	Never
I included everyone in our work.	Always	Sometimes	Never

Group evaluation: The following rubric can be used to help students evaluate the progress of their group:

Group's Action Plan

Group's goal is: ……………………………………………………..

TASKS	*WHO DOES WHAT*	*EVALUATION*		
		FINISHED	*NOT FINISHED*	*NOT ATTEMPTED*

Overall comments on the group's progress:……………………………

Characteristics of Complex Tasks

- Multiple roles for participants based on learner strengths (desktop publisher, media manger, production manager, personnel manager).
- Multiple subtasks that contribute to the larger group task with each group member contributing.
- Discussion is necessary so students understand that it is acceptable to talk and seek and give help to other group members. Students learn to ask for help and keep asking for help until it is given and that it is important to provide explanations and not just minimal responses.
- Group product is the expected outcome. This may include a PowerPoint, diorama, information chart, role play, performance, or portfolios that illustrate the learning that has occurred.
- Students are taught to reflect on the process and outcomes. (What did we do that worked well? What do we still need to do? How can we do it?)
- Criteria for task completion are clearly stated and checked off on the criteria sheet.

Ways to Evaluate Students' Learning from Working on Complex Tasks

- Quality of the discussion can be determined by the questions asked and responses given (higher-level thinking questions that elicit explanations), depth of discussion (conceptual understandings expressed), and justifications and reasons provided.

- Product outcome – comprehensive, covered key facets of the problem, creativity in response. For example, the word web shown in Figure 1.2 may be one way of evaluating how students are linking key concepts to the earthquake topic.
- Process employed – inclusive of others, respectful to others, willingness to consider others' points of view.
- Student reflections on the activity – what they perceived they learned from it. For example, provide two or three questions to promote the thinking about what has been discussed or experimented with during the course of the lesson. Present each question one at a time:

What was the most interesting thing that you learned today?
What would you like to learn more about?
Write a question about an idea or experiment that could help your group to think about one of the issues in the lesson.

Note: The completed team word web provides a natural tool for assessing group functioning; if each student writes in a different colour and the colour code is placed at the bottom of the team word web, the teacher can see the contributions made by each team member. It can also be a very interactive activity that generates a lot of focused discussion among students (Figure 1.2).

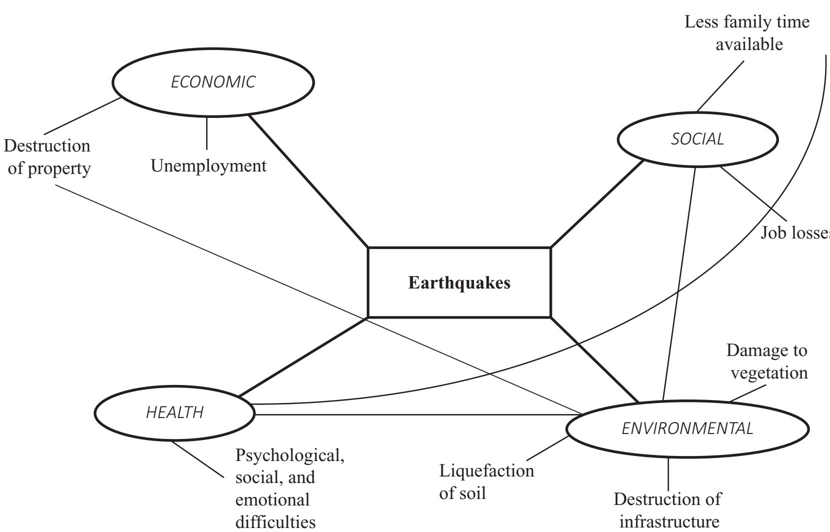


FIGURE 1.2 Team word web on earthquakes.

CHALLENGES IMPLEMENTING INQUIRY-BASED SCIENCE

One of the challenges teachers confront in teaching inquiry-based science is the misconception that they hold about what inquiry science involves. Many teachers, for example, often think they are "doing inquiry" because they are out at the front of the classroom directing the inquiry or demonstrating how to do it. This is not inquiry science. Inquiry science requires teachers to be able to excite the students' interest in a topic and then provide them with opportunities to undertake the investigation either by themselves or preferably in collaboration with others. The teacher, though, needs to remain active in the lesson, guiding the students, asking questions to help them consolidate their understandings, and providing feedback when needed to help students reflect on how they are progressing.

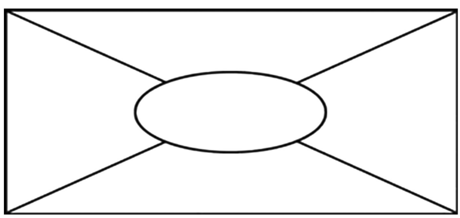
When students have opportunities to engage in scientific inquiries, they learn to use their ideas and, in so doing, deepen their conceptual knowledge and understanding of scientific content as well as their understanding of how to engage in doing science. Opportunities to experience science by doing it helps them to reconcile content knowledge with process skills, enabling students to engage more successfully with complex science ideas. Teachers can gauge the success of their teaching through students' level of engagement with the topic and each other, the scientific language students use to communicate their ideas, and the quality of the work they produce. Subtle comments such as "Are we doing science today? I really liked the way we did…" are typical of the types of comments students will make when they enjoy participating in science investigations.

A second challenge teachers confront in teaching inquiry-based science is how to establish small groups so students have opportunities to collaborate on topics that they are investigating. Placing students in ad hoc groups and expecting them to cooperate does not always guarantee that they will. Research demonstrates that groups are more likely to cooperate when they are well-structured so students understand how they are to work together, contribute information and ideas, accept responsibility for completing the tasks assigned to them, and assist others' to do likewise. When groups are established so these elements are evident, they are referred to as well-structured groups. In contrast, groups that are unstructured have many of the characteristics of traditional, whole-class settings where there is no requirement for students to work together to achieve the group's goal, leaving students to either work in competition with each other or individually to achieve their own ends.

Structuring a Cooperative Learning Activity

Students are organised into groups of four members and provided with the following visual organiser. Each student collects information on the topic and inserts that information in one of the quadrants to share with others in their group. This activity provides students with the opportunity to record what they know about a topic and then to negotiate with group members to select the best ideas to be inserted in the oval in the centre of the organiser. For example, students may be asked to respond to the following questions: “What are some various kinds of micro-organisms? Why is it important to know about them?” Once students have agreed on the best ideas, one member of the group then reports on these ideas to the larger class where other students, in turn, have opportunities to question the group about their selected ideas.

Visual Organiser for Cooperative Group Work



CHAPTER SUMMARY

This chapter has highlighted the importance of engaging students’ interest in inquiry science by having them do science where they learn to investigate topics together and engage in processes communities of scientists employ when seeking solutions to problems at hand. In doing science, students learn to explore possible solutions, develop explanations for the topic under investigation, elaborate on understandings, and evaluate or assess their conceptions using discipline-specific reasoning skills and practices. There is no doubt that good teachers engage students’ interest through novelty, something unusual that spurs their curiosity, and then use language that is very dialogic or language that lets students know that they are interested in what they think or want to say about the topic. Good teachers, then, carefully guide students as they begin to explore or investigate the topic, being careful not to dominate the conversation but allow students time to develop responses or think about the issue more carefully. In this sense, they give students the time to reflect and think more carefully about issues. However, good teachers are always careful to ensure that the inquiry-based science lesson moves forward and they do this by asking questions that probe and challenge students' thinking as well as giving them feedback that is meaningful and timely.

Teachers who do inquiry well tend to have a very good understanding of both the content that they teach and the processes involved. They use language that is very collaborative and friendly and take a genuine interest in what students are doing. They ask questions that challenge students' thinking. There is no doubt that children will engage in higher-level thinking if teachers give them time to talk about a topic; making explicit the types of thinking they need to demonstrate. When this occurs, students tend to be more focused and explicit in the types of responses they provide and the help they give to each other; language that is associated with successful learning.

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