I have found that many students who are not mathematically adept, or secure in their mathematical ability, adopt this triangle technique with confidence and achieve considerable success. It serves to demystify the maths of chemistry and to remove the almost crippling fear of maths that some students, especially older women, bring to their university studies. Having gained some confidence, students can then move on to develop a more mature understanding of the chemical concepts and the maths. The lesson for me was that there are many ways of learning without requiring full theoretical knowledge of all subject areas. It also reinforced my belief that learning is a journey shared, and that as educators we can still learn from our students, as I did from Tennille when she first showed me this triangle.

Levels of Enquiry

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Abstract

Enquiry learning can produce impressive cognitive and affective outcomes. However, there are different types/levels of enquiry. This hierarchy can be used to assess the degree of enquiry of an activity, to suggest how the enquiry level of an activity might be adjusted, to design enquiry activities, and to better sequence enquiry activities during a course of study.

To be regarded an enquiry activity, a learning experience must require students to answer a question by analyzing information themselves (Bell, Smetana, & Binns, 2005). The question, the method(s) used to collect information, and/or even the data itself may be either student-generated or provided by the teacher, the activity need not require the hands-on manipulation of materials, and it may also be conducted at a site beyond the classroom, such as a park, nursery, pet store, or museum. For example, having students observe the Moon over a 1-month period and determine the sequence of its phases is an enquiry activity, and enquiry can also include computer simulations, demonstrations, and the use of authentic data from the World Wide Web. There are also many other types of worthwhile science activities, such as the gathering of information from a library and construction of a scale model of the solar system, that do not satisfy the criteria for enquiry (i.e., students are not analyzing data to answer a question).

The benefits associated with enquiry methods of learning are impressive. They have resulted in "significantly improved mastery of science content, content retention, enhanced critical thinking skills, laboratory skills, and attitudes when compared with traditional teaching methods" (Smith and Mao & Chang, cited in McComas, 2005, p. 25). There are also different levels of enquiry, as summarized in Table 1, which is a modification of the rubric presented by Bell et al. (2005).

The four levels of enquiry shown in Table 1 reflect an increase in the cognitive demand on students as one moves from Level 1 to 4, and are distinguished by what is supplied to students. In a Level 1 enquiry activity, students use given materials/resources, the method to be used to collect data/information, and subsequent questions that show how to analyse the information to confirm something that has already been taught. Changing this to a Level 2 enquiry can be as simple as having students carry out the activity before understanding of a concept is otherwise developed, rather than afterwards, thus requiring them to analyse information to reach their own conclusion (or answer, or solution).

Table 1
Four Levels of Enquiry

Level	Type	Question	Method	Conclusion
1	Confirmation	Yes	Yes	Yes
2	Structured enquiry	Yes	Yes[a]	No
3	Guided enquiry	Yes	No[b]	No
4	Open enquiry	No	No	No

[a]Variations include not showing students how to present their data, mixing up the steps, and providing a less-than-perfect method.
[b]Variations include providing data table headings, providing the first few steps only of the method, and providing the materials to be used.

Level 1 and 2 activities are commonly referred to as "cookbook" activities, reflecting the fact that step-by-step instructions are provided, just as in a cookbook, and are the types of activities most commonly found in textbooks. While they do have a place in the science curriculum, we also need to take advantage of the benefits associated with carrying-out higher level activities, benefits that include greater student ownership of their work and more authentic decision-making.

Remove the methodology from a Level 2 activity and one arrives at Level 3, although various variations can be used to ease this transition. These include the following:

- While students are given the method, they are not shown how to present their data.
- Mix up the steps to be used, requiring students to reorder (cut-and-paste, say) them before proceeding.
- Provide a less-than-perfect method, ideally including common misconceptions, that students first need to evaluate and revise.

The following variations, to Level 3 activities, may also be used to help the transition from Level 2 to 3:

- Provide students with data table headings only.
- Provide the first few steps only of the methodology.
- Provide the materials to be used.

Level 4 enquiry is typified by topic-related research, and science fair, projects.

The progression from Level 1 to 4 has been described as a progression from teacher-directed to student-directed, closed to open, and passive to active learning. Table 1 may be used to assess the degree of enquiry of an activity, to suggest how the enquiry level of an activity might be adjusted, and to design enquiry activities.

We need to provide for students to progress from lower- to higher-level enquiry activities as a course of study, or an academic year, progresses. "Throwing" unprepared students into a Level 4 activity may be as unproductive, in terms of both cognitive and affective outcomes, as the other extreme of restricting their experiences to Level 1 and 2 activities only.

References

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Co-teaching as an Approach to Enhance Science Learning and Teaching in Primary Schools

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Abstract

In this article, we explore some of the experiences of student teachers, classroom teachers, science teacher educators, and children in co-teaching contexts in primary schools. The model of co-teaching adopted enabled student teachers (science specialist), classroom teachers, and university tutors to share expertise and work as equals, without mentoring, supervision, or assessment, to affect exciting learning opportunities for the children and for each other. Co-teachers planned, taught, and evaluated lessons together, and were encouraged to experiment with different learning and teaching approaches. The opportunities for all concerned were many. Students experienced an increase in their confidence to teach, and highly valued the more equal relationships they developed with the teachers and university tutors. The tutors also appreciated the improved relationships with students, the increased dialoguing with both students and classroom teachers about science, and the opportunity to reflect more on their own practice. Classroom teachers appreciated the opportunity to reflect in diaries that they kept, and greatly valued their own increased confidence in teaching investigative science. A survey of children carried out 6 months after the student placements evidenced their improved attitudes to school science, and fewer gender differences, compared with non-project children. Co-teaching constraints included the individual concerns of some students and teachers about their respective roles. The opportunities offered by co-teaching arose from processes such as the sharing of expertise, individuals working together with the same objective of enhancing children's science learning, the participation of science teacher educators, and the science workshops that took place in the university. (This paper is a summary, and update, of Murphy, Beggs, Carlisle, & Greenwood, 2004)

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Readers' Forum

Depth Versus Breadth

There is a tension between teaching for depth and teaching for breadth. Science education research points to the benefits associated with teaching for deeper, more meaningful understanding. Such an approach:

- Fosters critical thinking.
- Provides the solid foundation necessary for the building of further concepts, and for the