Learning science through practical experiences in museums

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School excursions to museums can form an integral and innovative component of school practical learning in science. Museums, however, are informal learning environments where teachers have limited control over the specific ideas or experiences with which the students are engaged. For school groups to make successful use of museums as learning resources, appropriate teaching and learning approaches and strategies, involving a shift from task orientation to student-centred learning orientation, are needed. By allowing student learning to happen in a natural way, that is, by allowing personal interest and curiosity to drive the students' learning, not only will students be gaining more from their excursion, they will be practising scientific investigative processes. Incorporation of the excursion into school-based investigations renders the purposes for the visit clearly apparent, and gives students a goal to achieve back at school using the information gathered at the museum. This article investigates how museum visits can be used to meet three major purposes for practical work, and introduces a framework to facilitate students' learning in museums.

Learning through practical experience

Practical work has become an integral component of primary and secondary school science in Australia, as in many other countries. Over the years, however, the term practical work has come to mean little more than hands-on activity which has something to do with science. The emphasis on the use of our hands and the insistence on the need for a laboratory, rather than on learning processes, has curtailed opportunities for giving students a full range of experience with the practices of science and its integral role in our lives. Much school practical work is teacher-directed busy work, which is often poorly planned and ill-considered. As several authors have suggested, it has too often become distant from scientific investigation (Klopfer 1990, Claxton 1991, Hodson 1994, Nott 1996, White 1996).

To assist good curriculum design, it is helpful to regard practical work as having three major purposes:

- to deepen understanding of scientific ideas;
- to experience scientific processes;
- to acquire scientific research skills.

Hodson (1996) refers to these three goals as: learning science; learning about science; and learning to do science. Underlying these purposes is a further set of goals including self-motivation, stimulation of creativity, recognition of the relevance of scientific understanding, and independent thought. Furthermore, as
Woolnough and Allsop (1985) point out, practical work can be regarded as comprising experiences, exercises and investigations. By cross-matching these three ‘styles’ or strategies with the three main purposes, a useful mix of student activities can be achieved. One of many possible matches leads to a programme of practical work consisting of:

1. having experiences which facilitate understanding of scientific ideas;
2. carrying out investigations using scientific processes;
3. conducting exercises which lead to acquisition of scientific research skills.

This combination of programme components provides a platform for discussing the utilization of museum environments for practical work. I will address each in this article, following a brief look at the nature of learning in museums.

Learning in museums

Learning processes in informal settings are different in many respects from those associated with school. They are non-directed, exploratory, voluntary and personal, and proceed through curiosity, observation, activity, a sense of wonder, speculation and theory testing (Ramey-Gassert et al. 1994). Museums are informal settings where visitors are invited to choose their experiences, where ideas may not necessarily be met in sequence, where learning may be fragmentary and unstructured, where learning is collaborative. Learning in informal settings is driven by curiosity and maintained by meeting a challenge and gaining satisfaction. Personal ownership of the learning is a fundamental component.

The active processes of constructing meaning from sensory input and curious observation are, at the same time, the essence of practical science (Hein 1996).

...the constructivist view emphasises the active and imaginative dimensions of learning and discovery. (Russell 1995: 19)

Museums, the places of musing, or of ‘gazing meditatively or wonderingly’ (Macquarie Dictionary 1981), are ideal settings for active, contemplative learning. While museums and science centres may not come readily to mind when thinking of school practical science, I would like to explore their potential for meeting the three components of the practical work programme described above. In the following section I shall discuss how an understanding of the features of museums and museum learning can be used to extend students’ experiences with the components of practical work.

Learning through practical experience in museums

Having experiences which deepen understanding of scientific ideas

Practical work may provide students with experiences which reinforce theoretical ideas they encounter, and may help them to make sense of their world. Hodson (1994) reminds us that the first step toward making sense of our world is familiarization with that world. Sense-making is determined by our experiences, specifically experiences which are not merely events which happen, but events which connect with other experiences to make things meaningful (Dewey 1958). The unique and vital contribution that a museum makes is the opportunity to confront
the 'real thing', and in many cases to experience the range and variety of 'real things' through sensory interaction. Thus, visitors can use museum objects to extend their perceived realities and pre-existing mental constructs (Dierking 1996). However, since visitors select their experiences and encounters, they are likely to develop a wide range of perceptions and understandings of the world (Bentley and Watts 1994).

Learning is a very individual process and museums provide good opportunities for people to learn independently and by choice. While exhibits are generally structured and sequenced, few visitors use the displays in this way (Falk and Dierking 1992). Although visitors may be aware of the structure and this may form a background to their viewing, they generally select what they view based on attraction to particular displays. This attraction may be related to size, colour or activity level, or it may be a much more personal matter, where the exhibit has some elements to which the visitor personally relates, or in which they have a particular interest. For whatever reason, it arouses their curiosity. Museums incorporate a range of opportunities to accommodate a variety of learning styles and strategies. For example, most museums and science centres include a mix of static displays, demonstrations, hands-on exhibits, interactive exhibits, videos and multimedia interactives, so that visitors can choose the styles of displays as well as the content with which they wish to engage. In this way, they can readily accommodate to personal learning styles and interests.

Finally, the understanding of scientific ideas can involve two levels of learning, which Golley (1988) terms the analytical or microscopic and the synthetic or macroscopic. On the one hand, museums provide unique opportunities to closely examine objects or specimens to understand detail such as animals’ claw shapes or other adaptations. On the other hand, museums allow appreciation of the big picture by providing a wide range of specimens or objects to allow comparisons, trends and patterns to be appraised.

Carrying out investigations using scientific processes

As argued above, emphasis on the use of our hands and the perceived need for a laboratory has narrowed opportunities to give students experience with the processes of science. To help students gain experience and understanding of scientific processes they need time to play and experiment both with ideas and with their hands, to ask their own questions and then seek answers. Genuine investigation demands time for contemplation and synthesis of prior experiences with newly encountered evidence. 'Time is needed for students to consider whether results 'add up, make sense and feel right' (Siu 1975: 16) and, if they do not, to investigate why. Students also need the opportunity to recognize that scientific investigation can incorporate a variety of data sources, both first- and second-hand; and that consideration and incorporation of existing views in the development of one's own ideas is not only a basis of learning, but is an integral part of the scientific process. Museums are reference sources which go beyond normal classroom resources. Museums can present the progression of scientific ideas through comparisons between real objects, such as the development of knowledge in astronomy through examination of instruments used. Current scientific research techniques and processes in areas such as genetics are exhibited through case studies of practising scientists. The tentative and changing nature of scientific understandings can be
grasped through displays of changing views on human evolution. Providing students with access to the processes by which scientists have generated new knowledge equips them to further their personal investigative learning endeavours (Hodson 1994, 1996).

Museums provide insights into 'ideas related to the collection, validation, representation and interpretation of evidence' (Gott and Duggan 1996: 793). The displays themselves offer opportunities for students to gather data in a way different from that in the laboratory. They foster close and detailed observations, comparisons and deciphering of patterns in data. They allow the testing of theories and predictions through direct observation. Natural learning processes in museums incorporate sharing and communicating of ideas and constant raising of questions. Museums can encourage the creative aspects of science such as hypothesis construction and experimental design using the breadth of data presented (Bloom and Powell 1984).

The opportunity to explore using our hands and our minds is provided by museums in numerous and varied ways. In some museums this is done by placing interactive exhibits in the context of the theoretical or historical displays, for example at the Maritime Museum (National Galleries and Museums on Merseyside) in Liverpool and Scienceworks in Melbourne. Other institutions present a range of interactive displays with a strong central theme (for example, the environmentally based Discovery Space at the Australian Museum in Sydney or Minegames at ScienceWorld in Vancouver). The Museum of Science, Boston is developing a series of exhibits each concentrating on a particular scientific process such as Observation. The new Chicago Academy of Sciences Museum incorporates environmental studies in laboratory, display and field contexts.

One of the criticisms levelled at science centres has been the apparently unstructured play which takes place. Yet learning, and particularly science learning, is itself a playful process. Semper (1990: 54) elaborates:

...play is rarely considered a significant part of learning... But play is a serious matter in science education. It leads to the development of skills in observation and experimentation and the testing of ideas, and it provides an opportunity to independently discover order in nature.

Learning involves toying with ideas in an attempt to reduce complexities until simple and elegant generalizations emerge, it involves time to explore and become thoroughly familiar with objects and ideas (Duckworth 1992). Playing with our minds and playing with our hands are not mutually exclusive activities. One can and often does lead to the other. In developing the Exploratorium in San Francisco, Oppenheimer (1968: 174) considered that science museums provide 'an environment in which people can ask questions and answer them by their own experimentation'. They offer an opportunity for students to adventure, take risks and learn through failure (Hodgkin 1985).

Conducting exercises which lead to acquisition of scientific research skills

Several authors (for example, Harlen 1985, 1992, Sheppard 1993) describe skills involved in scientific inquiry which are directly applicable to learning in a museum: observing and exploring, raising questions, proposing ways to answer questions, examining, comparing, analysing, finding patterns in observation, eval-
valuating, classifying, applying ideas in new situations, gathering information, recording observations systematically, analysing, using evidence critically and logically, communicating information in various and appropriate ways.

In museums students can develop perceptual skills that teach them how to gather information from objects and experiences. They can have meaningful learning experiences by allowing the objects to be the primary means of communication (Sheppard 1993). Duncan Cameron, quoted in Voris et al. (1986: 3), adds:

Surely the goal [of museum visits] is to open up the world of sight and sound and touch for each child, by sharpening his perceptual skills, and to make him [sic] sensitive to new sources of data in the world around him. It is to develop each child's inductive skills so that he can form more meaningful relationships with his environment.

The skill of selecting and recording relevant information in a useful manner can be practised particularly effectively in a museum setting. Museums offer a large range of information which may seem overwhelming to students. By helping students to recognize the way in which this information is classified or displayed will in turn help them to learn how to select, sort, classify, code, synthesize and analyse information and, finally, how to communicate it. Tasks involving these skills will teach students that classification and recording of data can be based on clear and stated criteria, and that the methods will be influenced by the purpose for which it will be used, such as to show relationships between animals, or chronological development of technologies.

Observations and data gathering in a museum can lead to further questions for investigation. In some instances these questions may be answered through further examination of the objects and information available at the museum. Alternatively these questions may be answered through experimental processes carried out back at school.

Facilitating learning in a museum

Successful management of museum experiences which address these three components of practical learning programmes will help students to recognize that science is not just a school subject occurring in a laboratory. For this to occur, teachers need to take an active role in facilitating appropriate learning strategies which allow students to benefit from the full potential of museum resources. Previous research has shown that teachers in both primary and secondary schools in Sydney have a poor understanding of ways to facilitate learning during excursions to museums (Griffin 1995, 1996; Griffin and Symington 1997). Learning opportunities are hampered by over-use of a task-oriented approach in which teachers concentrate more on control and discipline than on student learning. In response, a School—Museum Learning Framework, with a theoretical base in research into school visits to museums, family group behaviours in museums, and social constructivist approaches to teaching and learning has been developed, and has been trialed by seven teachers from a range of schools.

The School—Museum Learning Framework (SMLF) involves students bringing their own chosen questions or 'areas of inquiry' to the museum, and ensures that students have considerable control over their learning, within parameters provided by the teacher. It rests on three Guiding Principles for teachers:
- integrate school and museum learning;
- enable self-directed ownership of learning;
- facilitate learning strategies appropriate to the setting.

The first Guiding Principle for creating effective conditions for learning is that the museum visit is embedded in a school-based unit of learning. If students are conducting an ecological study of their local environment, for example, then a visit to a natural history museum is one part of the investigation. If the students are studying work and machines then a visit to a science museum or science centre is an integral component. By placing the museum visit firmly in a school-based learning unit, clear learning purposes for the visit can be established. In the first example, the students may wish to investigate the animals' adaptations for feeding, or the relative sizes of the prey and predators in their region, or gather data on the survival requirements of each of the animals they know to be in their environment. This information can then be placed back into the context of their local environment and used to help answer their investigation questions. For example, it will help students to build a food web for their environment, or answer questions about the relative numbers of different species found in the field investigations. In the second example, the students may find answers to questions about the applications of different simple machines in everyday equipment. They may be able to make comparisons between the use of these principles in present and past times and then consider why there have been changes. If there are hands-on exhibits, they may be able to experience the different effort required to lift a very heavy object using a range of pulleys; or examine a cut-away of a complex machine to determine the use of a range of simple machine principles. Further questions can be raised which may spark investigations back at school. Can they design a better version of the machine they have seen?

The second Guiding Principle is to give the students as much ownership of their learning as is possible. Students are encouraged to develop their own areas of inquiry to take with them to the museum – perhaps selecting a particular group of animals to investigate for the ecological study example given above, or a particular set of machines for the 'work and machines' study. Alternatively, they may choose to investigate more widely – for example, protection from predators by all the animals they know to be in their environment, or investigation of the conditions under which one machine is more efficient than another. Allowing students to select their own area of investigation as the basis for their viewing provides personal incentive and ownership of learning.

Among the most common concerns expressed by students in my study of current practices was that they had to stay at exhibits for too long, or they did not have long enough to see what they wanted (Griffin and Symington 1997). Once students have seen what they want in a particular room, they naturally become restless and off-task behaviours may emerge. The learner-centred climate of the SMLF allows students to move where and when they wish within constraints required for safety and supervision. This can be managed in several ways. A successful option is to have sufficient adults accompanying the group to allow small groups to operate independently.

The third Guiding Principle is to address the environmental needs of the students. A museum is an unfamiliar learning environment for most students. Discussing with students the purpose of the institution, the roles of people who
work there, and the method of specimen and display preparation will all reduce distractions on arrival and focus students’ attention. In addition, physical orientation to the venue before and on arrival will help students to locate quickly the parts of the venue that they wish to visit and will reduce the possibility of students becoming lost, and assist them in finding the restrooms and refreshment areas. Research into family group behaviours in museums reveals that the majority of groups take a break after no more than an hour, need to sit down when possible, and talk to each other a great deal. These physical needs must be built in to school excursions as well.

Further, observations of school groups in my research revealed ‘waves of concentration’ by the students. There was an apparent need for ‘mental’ rests, in addition to physical rests. Allowing students periods of superficial viewing appeared to facilitate a return to more focused and concentrated learning activity within a short time period. This observation, coupled with those of family groups, suggests that teachers need to allow their students short physical and mental breaks, rather than cajoling them ‘to keep working’ and ‘not to waste time’. It may be that by ‘keeping on working’ they will in fact waste more learning time, as their overall capacity to synthesize information may decline.

The learners’ inquiry approach used in my trials of the SMLF embodies the scientific process of inquiry and learning. It involves the four key steps of developing questions, gathering data, analysing data and synthesis of information. One of the most significant outcomes of its application to school—museum visits was clear recognition by the students of their own level of learning. Further, the majority of students interviewed talked not only about their learning, but about their enjoyment of learning. Many commented that they enjoyed the excursion because they were learning and having fun. While laboratory-based practical work is often claimed to have motivational value, research support is somewhat ambiguous (White 1996). By contrast, the motivational value of experiences based on the SMLF is clear.

Conclusion

There is a direct link between self-driven learning in museums and practical learning of science. Like all learning, the learning which takes place in museums, whether we are looking for ‘practical’ learning or cognitive learning, is impacted on by the learner’s prior experiences, current conceptual understanding, expectations, and attitudes. In the same way that providing students with a recipe to follow and then recording the correct result from the blackboard is anathema to scientific investigation, taking students to a museum without a clear shared purpose, student ownership of the learning and a goal to achieve with the gathered information, may be a waste of the time and money invested in school excursions.

By incorporating the three Guiding Principles developed through my research into school—museum learning – (1) integration of school and museum learning; (2) provision of opportunity for self-directed ownership of learning and (3) facilitation of learning strategies appropriate to the setting – the three key parameters of purpose, ownership and choice will ensure that students will be learning science, learning about science and learning to do science on school excursions to museums.
Moreover, if students can be encouraged to enjoy and to recognize resources like museums as interesting places for lifelong learning, then we can help students to see science and practical science as something beyond a school subject.

If we wish [students] to develop their own judgement we should encourage them to use it. If we wish them to trust their senses and observe accurately, we cannot at the same time tell them 'what they should have seen'. If we wish them to be interested in finding answers to their own questions, we cannot hope to train them by working on our questions....The ability to see the relevance of something known to something new is not a matter of 'intelligence' or 'effort' or 'depth of understanding', but of experience, and of the specific strategies, born of experience, that a learner possesses for generalising and extending their knowledge modules into unknown territory. (Claxton 1993: 206)

Note
1. The word 'museum' is used as a generic term to include science museums, science centres, natural history museums, zoos and gardens.

References


