DOCUMENT RESUME

ED 391 673 SE 057 648

AUTHOR Rennie, Leonie J.; McClafferty, Terence P.
TITLE Using Visits to Interactive Science and Technology Centers, Museums, Aquaria and Zoos To Promote Learning in Science.
PUB DATE [95]
NOTE 21p.; This paper received the 1995 award for the Implications of Research for Educational Practice from the Association for the Education of Teachers in Science. An earlier version of this paper was presented at the Annual Conference of the Australian Association for Educational Research (Fremantle, Western Australia, Australia, November 1993).
PUB TYPE Information Analyses (070)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Aquariums; Educational Research; Elementary Secondary Education; Foreign Countries; Literature Reviews; *Museums; *Science Instruction; Teaching Methods; *Zoos

ABSTRACT

Interactive science and technology centers are flourishing throughout the world. Displays in museums, aquaria and zoos are becoming much more interactive. These places offer exciting opportunities for school children to experience science and technology in a stimulating environment. But do such centers affect learning? Do they offer valuable motivational opportunities for students to learn science? If so, how can teachers use them to promote students' engagement in school science, which might seem boring and mundane by comparison? A review of research related to science learning is presented, together with a summary of findings intended to assist teachers to use these centers effectively. Contains 104 references. (Author)

Using Visits to Interactive Science and Technology Centers, Museums, Aquaria and Zoos to Promote Learning in Science

Léonie J. Rennie and Terence P. McClafferty

Key Center for School Science and Mathematics

Curtin University of Technology

GPO Box U1987

Perth, Australia, 6001

Home Phone (61) 9 330 1636

Business Phone (61) 9 351 7484

Fax (61) 9 351 2305

email irenniel@info.curtin.edu.au

email rmcclaff@cc.curtin.edu.au

This paper received the 1995 Award for the Implications of Research for Educational Practice from the Association for the Education of Teachers in Science

(An earlier version of this paper was presented at the Annual Conference of the Australian Association for Educational Research, Fremantle, Western Australia, November, 1993)

Using Visits to Interactive Science and Technology Centers, Museums, Aquaria and Zoos to Promote Learning in Science

Abstract

Interactive science and technology centers are flourishing throughout the world. Displays in museums, aquaria and zoos are becoming much more interactive. These places offer exciting opportunities for school children to experience science and technology in a stimulating environment. But do such centers affect learning? Do they offer valuable motivational opportunities for students to learn science? If so, how can teachers use them to promote students' engagement in school science, which might seem boring and mundane by comparison? A review of research related to science learning is presented, together with a summary of findings intended to assist teachers to use these centers effectively.

The growth in the number of interactive science and technology centers and interactive displays in museums, aquaria and zoos has been accompanied by an increase in the number of school visitors. School groups are a major target audience for these centers because they offer exciting exhibits and themes, providing opportunities for students to experience science and technology in a stimulating environment. Conventional wisdom suggests that students enjoy their visit, and probably learn something, too. For example, Falk and Balling (1979) asked elementary school teachers and administrators, college method lecturers and nature center professionals about their opinions of the value of field trip experiences. They believed that the development of positive attitudes and cognitive learning were the most important outcomes. Do visits result in significant learning? Does the excitement of the visit, particularly to a hands-on, exploratory center, result in better learning back at school? Or does the stimulating visit just make school science seem boring and mundane by comparison? This paper synthesizes educational research about learning in interactive science and technology centers, museums, aquaria and zoos, subsequently referred to by the generic term "science centers", and distils from it guidelines for science teachers to ensure that class visits do enhance the learning of their students.

Background

The educational potential of science centers is well recognized (Boyd, 1990; Semper, 1990), although as some reviewers point out, much of the literature which promotes them is based on little more than anecdotal evidence (Ramey-Gassert, Walberg & Walberg, 1994). In 1970, Sorrentino and Bell listed 16 values attributed to science field trips by educational texts and periodicals, and then compared these judgmental values with empirically determined values. They found that only six of the 16 values had been studied empirically and called for substantial experimental research to provide more evidence. In the following 25 years the research literature concerning visits to science centers has expanded dramatically (Bitgood, Serrell & Thompson, 1994; Bitgood, 1989a; Screven, 1984), but it is not all in the science education literature, and much of it is piecemeal.

In science education, much of the early research and opinion referred to "field trips". Sorrentino and Bell (1970, p. 233) defined field trips broadly as "any journey taken under the auspices of the school for educational purposes", but until recently, the focus remained on out-of-door field experience and this was reflected in reviews (Mason, 1980; Prather, 1989). Some authors have described research findings from science centers and drawn implications for teachers (Bitgood 1989b; Follette, 1987; Koran & Baker, 1979), science center personnel have offered guidelines for visits based on their own observations and experiences (Barrett, 1965; Beardsley, 1975; Griffin, 1988), and other authors have focused on procedural aspects (Hoke, 1991; Shepley, 1974). Krepel and DuVall (1981) combined research and experience to offer step-by-step instructions for field trips in a number of subject areas. What has been lacking thus far, is a theoretical rationale which integrates the range of research findings available in the literature, and can be used by researchers and teachers to understand how to make best use of their science center visits.

Based on their extensive experience, in both museum and science education, Falk and Dierking (1992) recently drew together current knowledge about how the public, including school groups, uses museums and other informal educational institutions and proposed their Interactive Experience Model. They conceptualize the visit experience as an interaction among three contexts: personal, social and physical. Simply put, they suggest that what happens in terms of outcomes from visits depends on visitors' own personal background of knowledge, experience, skills, motivations and desires; their social interactions during the visit; and the physical environment created by the exhibits and their surroundings. Falk and

Dierking's model suggests that visitors construct their own unique meaning for the visit experience, according to personal background and interaction with the social and physical environment. Falk and Dierking submit that their model provides a framework for making sense of what happens during visits to a range of educational institutions. For science educators, the model translates to the easily comprehensible idea that outcomes from the visit experience are inextricably bound with what happens before, during and after the visit. It follows that for successful visits, teachers need to know how to integrate the personal, social and physical contexts into a coherent visit experience.

This paper focuses on the experiences of a subset of visitors to science centers: the school group. The purpose of the paper is to examine critically the research literature in the area and to answer two questions: How do science centers affect learning? How can teachers use them to promote students' engagement and learning in school science? The first part of the paper addresses the first question and presents a review and synthesis of research findings related to the visits of school-aged children, particularly in school groups, to science centers. The paper does not consider research relating to family visits, except where the findings are relevant to school-age children. (Dierking & Falk, 1994, and McManus, 1994, provide useful reviews on family visits.) This review is organized around three headings: Why visit a science center? What happens there? What are the outcomes? In the second part of the paper the review and synthesis are structured into a framework to address the second question of how teachers can use science centers to promote students' engagement and learning in school science. The framework is educational rather than procedural in focus, requesting teachers to consider carefully their reasons for making the visit.

Review of Research about Visits to Science Centers

Why Visit a Science Center?

Teachers give a number of reasons for taking their class to visit a science center. Gottfried (1980) reported that teachers' visits to the Biolab, at the Lawrence Hall of Science, included the desire for a "change of pace", science enrichment, a social experience for the students, and to increase their exposure to science. Rennie and Elliott (1991) found that teachers took their classes to a science center in Western Australia for similar reasons. There is another reason to visit. Recent research has shown that visits to science centers are memorable events (McManus, 1993a; Stevenson, 1991; Wolins, Jensen & Ulzheimer, 1992). Memories are persistent in the minds of children and remain with them into adulthood. Falk and Dierking (1994) interviewed middle school children and graduating college students and found that 80% of them were able to recall three or more specific things linked to a field trip during their first, second or third grade. Thus, an effective teacher can call upon the visit experience later, in appropriate learning situations.

If the purpose of a visit is essentially related to entertainment, such as a reward for students at the end of term, a social experience or a change of pace, the learning outcomes will be quite different from those of visits which are structured to perform a specific role in a sequence of school work. In the following sections, the reasons for these differences in outcomes become clear.

What Happens During the Visit Experience?

Visitor Behavior

What casual visitors do at science centers is well documented and remarkably consistent. They orientate themselves for the first few minutes, attend to the exhibits for some considerable time, about 30 minutes or more, and then "cruise" for a further period, perhaps 15 to 30 minutes (Diamond, 1986; Falk, Koran, Dierking, & Dreblow, 1985; Stevenson, 1991). Similar behavior is observed for children, with a period of "roaring around" followed by "settling down" (Carlisle, 1985; Javlekar, 1989). From their extensive evaluations, Price and Hein (1991) suggest that a visit of two hours is an appropriate length, as shorter visits can lead to a lack of involvement, and longer visits result in a lag of interest.

If they are visiting a particular science center for the first time, exploration and setting-orientated learning is a high priority for students, and in a new, unfamiliar setting this behavior takes precedence over the teacher's plans for the visit (Falk, 1983a; Falk, Martin & Balling, 1978). Children familiar with a setting tend to learn more than those who are not

(Balling & Falk, 1980; Wolins et al., 1992), although if students are very familiar, they may find the setting or the exhibits boring (Balling & Falk, 1980; Falk & Balling, 1982; Talisayon & Talisayon, 1987). Balling, Falk and Aronson (undated) demonstrated that orientation programs facilitate cognitive learning from a zoo visit, especially when conducted by the teacher. Research on the use of novelty reducing interventions, such as slide shows of the venue before a visit, indicates that the amount of purposeful exploratory behavior can be increased (Kubota & Olstad, 1991).

Interacting with Exhibits

Once students begin interacting with the exhibits, they tend to do it in a stop-start manner, revisiting exhibits that interest them, often several times (Carlisle, 1985; Tuckey, 1992). It is clear that students' prior knowledge is important in determining how they interact and what they learn from exhibits (Beiers & McRobbie, 1992; Falk, Koran & Dierking, 1986; Gottfried, 1979; Lucas, McManus & Thomas, 1986; Sneider, Eason & Friedman, 1979; Tulley & Lucas, 1991). Children need time to "mess about" with new or unfamiliar equipment before they begin serious work (Hawkins, 1965), and the same seems to be true in museums. Students, even undergraduate students, need time to play with and explore the exhibits before they begin to understand them (Semper, Diamond & St. John, 1982).

Falk (1983b) has found that both the time spent at an exhibit and the nature of the interaction affect the amount of learning which occurs. Interaction with exhibits is most effective when children's thought processes match those required to understand the exhibit (Boram & Marek, 1991; Feher & Rice, 1985; Javlekar, 1989; Tuckey, 1992). Also, children's gender may affect their choice of exhibits and how they interact with them (Bremer, 1992; Carlisle, 1985; Hidi, Soren & Weiss, 1994; Koran, Koran & Longino, 1986), although there is no evidence that one sex has less positive experiences than the other (Boisvert & Slez, 1994; Stevenson, 1991).

Visit Structure

The structure of a visit can vary from free exploration of exhibits to a passive docent-led tour. Research suggests that neither extreme is effective; students need some structure, but also some exploration time (Bitgood, 1989b; Linn, 1980). Both cognitive and affective learning can be increased when teachers use structured activities before and/or after the visit to create a context for the experience and link it with classroom work (Finson & Enochs, 1987; Koran, Lehman, Shafer & Koran, 1983; Wolins et al., 1992). In fact, Finson and Enochs (1987) suggest that unstructured visits may cause anxiety in children, thus reducing their enjoyment. Other pre-visit orientation activities, including a variety of lectures about concepts, readings and other guide materials, provide structre and have been effective in promoting the learning of students (Gennaro, 1981; Melton, Feldman & Mason, 1936/1988; Stankiewicz, 1984) and young adults (Braverman & Yates, 1989). Griffin (1994) is examining the effect of having students develop their own questions to structure their visit experience.

An important aspect of structure is the means by which students are cued to the salient features of the exhibits. The most universal cue is the labelling of the exhibit and there is a considerable body of research about the optimal style and positioning of labels. This relates to exhibit design, and is not reviewed here (see, for example, Screven, 1986). Many visitors read labels and often read them to each other (McManus, 1989; Tuckey, 1992), although younger children are less likely to attend to labels (Carlisle, 1985; Hidi et al. 1994). Using wall panels to describe exhibit layout and sequence can be effective (Koran, Lehman, Shafer & Koran, 1983). The use of a series of programmed cards has been shown to enhance learning (DeWaard, Jagmin, Maisto & McNamara, 1974), presumably because the cards direct and sequence visitors' attention to important aspects of the exhibit.

Worksheets provide another kind of cue but their use is problematic. They can enhance learning by focusing attention on particular exhibits (Canizales De Andrare, 1990), but they can inhibit interaction (Parsons & Muhs, 1994). Price and Hein (1991) believe worksheets impede learning because they restrict the focus of children's thought processes and prevent them from thinking of their own questions to ask. Gottfried (1979) reported that no children in his study were observed to record on their data sheets, although his follow-up work indicated that learning had occurred. McManus (1985) suggests that for older students, one worksheet per group can be effective, because this promotes opportunities for meaningful, cooperative group learning rather than simply trading answers, as often happens with individual worksheets. Particularly with younger children, the worksheets should focus on the exhibit itself, rather than its labels, to encourage children to develop their powers of observation. Fry (1987) found that considerable effort is required to prepare good worksheets, that is, those which are linked directly to the exhibits, are unambiguous, emphasis interpretation, and are integrated with school work.

Docents or explainers (particularly when they lead structured tours) also provide cues by asking questions to help students to attend to significant aspects of the exhibits (Bennett & Thompson, 1990; Diamond, St. John, Cleary & Librero, 1987; Martin, Brown & Russell, 1991). Chaperones of school groups, usually parents or teachers, can also fill this role (Parsons & Muhs, 1994). The presence of explainers is important. Because students have different combinations of background experiences, interests and skills, they will interact differently with exhibits and thus need different kinds of help (Gottfried, 1979). Effective explainers try to open-up students' thinking rather than direct them to the right answer (Price & Hein, 1991), particularly during structured tours (Sakofs, 1984), and their effectiveness tends to be greater when the exhibits are not interactive (Lehman & Lehman, 1984; Stronk, 1983).

Social Context

The social context of the visit has a powerful influence on behavior and learning. Research suggests that interactions between people are at least as important for learning as those between the individual and the exhibit (Blud, 1990; Diamond, 1986), and McManus's (1987; 1988) extensive research led her to conclude that the social aspect of the visit is a fundamental source of satisfaction in museum visits. Peer-teaching is a frequent occurrence, with children taking on the role of explainers as they question their companions, read labels aloud, and demonstrate the way the exhibit works (Carlisle, 1985; Gottfried, 1980; Rennie & Elliott, 1991; Tuckey, 1992). Some students who are not usually successful in school may be successful peer leaders during visit activities (Gottfried, 1980). The optimum group size is small, so that students are more able to ask questions, receive answers and have their hands on the exhibit (Price & Hein, 1991). Gottfried (1980) and Tuckey (1992) report that pairs get most deeply involved in the activities. In larger groups, some members' experience may be vicarious, reducing the opportunity to learn (Tuckey, 1992). According to some research, children prefer to be with peer companions rather than adults (Birney, 1988) and many prefer to teach themselves, even when exhibits are not interactive (Stronck, 1983). Generally, children have been observed to behave in a more social way with each other than adults do, demonstrating more cooperative and sharing behaviors (Carlisle, 1985). In family visits, most of the social interaction is between adults and children (Hilke & Balling, 1985). Although students enjoy the social aspects of their visit, they also have solitary experiences, learning by themselves or by watching other people interact with exhibits (Tulley & Lucas, 1991).

Teachers' Involvement

What do teachers do during their class visits to science centers? Their involvement in the visit can be total, as in some classes observed by Rennie and Elliott (1991), or zero, for those teachers seen to disappear into the cafeteria during programs evaluated by Price and Hein (1991). Teachers' involvement is not limited to the duration of the visit. Price and Hein found that teachers were most enthusiastic when they were involved in the design and running of the visit program, but that they, themselves, needed preparation in order to effectively instruct their class. Balling et al. (undated) discovered that pre-trip instruction for a zoo visit was most effective when it was led by a teacher who had experienced a workshop by zoo staff. On the basis of their research, Gennaro, Stoneberg and Tanck (1982) recommend that pre- and post-visit materials are best developed by teachers working with personnel from the visit venue.

Even though teachers recognise the importance of preparing themselves and students for a visit (Falk & Balling, 1979), such preparation often never happens. Gottfried (1980) reported that none of the teachers in his study planned preparatory activities and only one-third planned follow-up activities. None of the teachers in Tuckey's (1992) study had prepared their children or linked the visit to any topic they were studying. The participation of teachers in their class visit can be very beneficial, even for teachers themselves. As Price and Hein (1991) report, teachers express surprise at how much, and which, students know about science when they see them interacting in the unstructured environment of the science center.

What are the Outcomes of Visits to Science Centers?

There are a range of possible outcomes from visits to science centers, although the measurement of them is not straightforward (Donald, 1991; Falk et al., 1986; Koran & Ellis, 1991; Koran, Longino & Shafer, 1983; Lucas, 1983; 1985). Many studies have reported a range of gains in cognitive learning and/or more positive science-related attitudes as outcomes of visits (Balling & Falk, 1980; Borun, Flexer, Casey & Baum, 1983; Dymond, Goodrum & Kerr, 1990; Eason & Linn, 1976; Erätuuli & Sneider, 1990; Finson & Enochs, 1987; Gottfried, 1980; Javlekar, 1989; Lam-Kan, 1985; Mallon & Bruce, 1982; Rennie, 1993; in press; Schibeci, 1992; Tuckey 1992; Wright, 1980), but the findings for cognitive and affective change are not always consistent (Price & Hein, 1991). For example, Stronck (1983) found that cognitive learning was enhanced by a structured, docent-led tour of a natural history gallery, but an unguided group reported more favourable attitudes. Flexer and Borun (1984) concluded that a well-structured class lesson was more effective in promoting learning than a visit to an exhibit at the Franklin Institute Science Museum, but the visit was perceived to be far more enjoyable and interesting. The students in Flexer and Borun's study considered themselves to be learning during their visit and some thought they learned more than in the classroom lesson. Similarly, children interviewed by Birney (1988) did not distinguish between learning and enjoyment. It is important to note that some exhibits may induce misunderstanding or misconceptions (Diamond, 1991; Tuckey, 1992), and misconceptions can interfere with learning (Borun et al., 1983).

These findings suggest that clear-cut, empirically-demonstrated cognitive gains from visits to science centers are not all that should be considered in deciding whether visits are beneficial. Koran and Koran (1986, p. 14) suggested that besides learning "curiosity, psychomotor development, interest, appreciation, motivation and generalization all could be considered among the desired outcomes of a museum visit". Gottfried (1980, p. 173) drew attention to the "unique type of self-motivated learning that occurs" during a school field trip to Biolab, and Stevenson (1991) reported that even six months after their visit to Launch Pad at the London Science Museum, families still talked to each other about their experiences there. Price and Hein (1991, p. 510) define "educationally effective programs as those in which products are not emphasized, inquiry is sparked, open-ended questions are generated, and students actively participate and appear involved." It is not surprising that their list of benefits from visits to science centers, aside from cognitive learning, include the excitement and pleasure children gain from visits; the ready involvement of non-academic and non-English speaking students; and the cooperative ways of working developed by students. An extensive ethnographic study of third graders (Wolins et al., 1992) found that the most powerful memories of visits include the affective or emotional content of the experience, often unique to the child, not the intended goals of the museum educator or teacher. McManus (1993b) argued that the distinction between cognition and affect is artificial and unhelpful in evaluating visit outcomes. It is clear, particularly in the context of Falk and Dierking's (1992) Interactive Experience Model, that both cognitive and affective aspects need to be considered in terms of the benefits of school visits to science centers.

Summary

The research reviewed provides answers to the first question posed in this paper. Visits to interactive science and technology centers, museums, aquaria, and zoos provide valuable motivational opportunities for students to learn science and they affect students' learning. Overall, the research suggests that students usually find visits enjoyable, but both the amount and nature of their cognitive and affective learning vary. The kinds of factors which affect the outcomes of visits can be considered in terms of Falk and Dierking's (1992) Interactive Experience Model: factors which relate to the personal, social and physical contexts of the visit. The factors examined in the research literature indicate that learning is influenced by the extent to which students are familiar with the setting, their prior knowledge, the match between the cognitive level of students and the thought processes required by the exhibits, the degree of structure of the visit, the provision and nature of the cues for learning, and the social aspects of the visit. Many of these factors are under the direct control of the teacher, thus it follows that teachers can influence the value to their class of visits to science centers.

Using Visits to Science Centers to Promote Students' Engagement in School Science

The guidelines in this section follow from the findings presented above and assume that teachers are organising a visit to a science center to enhance students' learning. Accordingly, students' personal backgrounds, and the social and physical environments must be considered in planning and implementing the visit and follow-up activities. The section is structured around the three phases of the visit to the science center: before, during and after.

Before the Visit

Teacher Preparation

Teachers need to visit the science center to discover what exhibits are there, what concepts or phenomena they demonstrate, what level of thought processes they require to be understood, whether there are worksheets or other cues are available, and how students' movement around the center can be organized. With this information, teachers can determine how to make the visit fit the needs of their current teaching program. They can select the exhibits which demonstrate the concepts they are teaching, and choose those which match the cognitive level of the students. They can devise learning activities built around the exhibits, in terms of pre-, post- and during visit instruction. Teachers should try to take advantage of the inservice courses many science centers provide to help them plan their visits (Pollock, 1983). Some centers are developing computer-based guides which can be used for orientation activities back at school (Morrissey, 1993).

Student Preparation

Informing students where they are going and determining their familiarity with the center helps teachers to consider whether novelty is likely to be an important factor in the visit. If so, teachers can decide whether to provide orientation information, such as maps. Procedural details, such as the location of the restrooms, where and when lunch will be eaten, the length of the visit, access to the museum shop may seem to be trivial points, but knowing these things reduces orientation problems and helps students plan their time. Sharing with students the educational objectives of the visit and involving them in planning are effective forms of pre-visit instruction (Follette, 1987). Knowing what learning objectives are targeted serves as an advance organizer for students and they can be more self-directed in achieving them. Related preparation for students includes providing them with a list of the exhibits to be visited (although they may visit others) and ensuring that they have the necessary background knowledge and skills to use and understand how the exhibits work. The nature and requirements of post-visit activities should also be made clear before the visit.

During the Visit

Orientation. Teacher should expect that students unfamiliar with the environment of the science center will require some time to settle down to work. Students will also engage in preliminary playing and exploration with exhibits even when they are seriously working.

Interacting With Exhibits. Besides helping students keep track of time and their learning objectives, teachers can provide cues to facilitate learning by being available to respond to questions and make suggestions to extend thinking and understanding. Students with different levels of skills may need different kinds of help. If students have a structured visit, they also should be given some time for free exploration.

Social Interaction. To capitalize on students' enjoyment of social interaction and the peer teaching which occurs, teachers should encourage students to work in small groups and share the responsibilities associated with learning.

Recording. If teachers have decided that students will use worksheets or some other means of recording their findings, this may be done most effectively with one worksheet or record per group.

Concluding the visit. Near the end of the visit, teachers may need to check how students are progressing in achieving the objectives of the visit, so they can structure the remainder of their time effectively, including "free" time.

After the Visit

The research literature speaks least eloquently about the nature of post-visit activities. Common sense suggests that teachers should plan them to reflect the varied experiences students will have at the science center. Young children in particular should be given the opportunity to share their experiences and findings with their peers through class presentations, group reports or posters. Students can plan further research or experiments based on what they have found out. In subsequent lessons teachers should take every opportunity to refer to exhibits and activities experienced during the visit, thus reinforcing and extending the learning which occurred.

Conclusion

The second question addressed in this paper was how can teachers use visits to science centers to promote students' engagement and learning in school science, which might seem boring and mundane by comparison? We think that, in three words, the answer is *don't compare, complement*. Students find science centers exciting and different from school, and the visits more interesting and enjoyable than effective class lessons, even when given in the museum (Flexer & Borun, 1984). It is not realistic to expect every class lesson to be as exciting as a visit to a science center, nor would that necessarily be an effective way to achieve the objectives of the science curriculum. Instead, we believe that teachers should integrate visits to science centers into their teaching program in ways which complement the learning activities at school.

In making visits integral to their program, we suggest that the teacher's most important decision relates to *why* they take their class to the science center. The reason for the visit determines how teachers should prepare themselves and their students to maximize the complementary effect. For example, if the purpose of the visit is to provide motivation, then the focus of the visit will be on affective outcomes, the arousal of interest and curiosity about concepts that the students are finding rather mundane at school. The venue and exhibits chosen will be those that relate to school work, but provide new (and perhaps extra-curricular) perspectives on those concepts. If the purpose of a visit is to provide an introduction to a new science topic, then the visit will need to be centred around a range of exhibits chosen because they demonstrate a variety of concepts to be covered in the topic, so that students will leave the center with a range of unanswered questions to pursue back at school. If the visit aims to revise and consolidate the learning of concepts, exhibits should be chosen which provide new demonstrations of the concepts, related phenomena and applications.

By taking account of students' personal background, acknowledging and harnessing the positive aspects of the social context, and having a thorough knowledge of the physical environment, teachers' planning can capitalise on the interactive nature of the visit experience (Falk & Dierking, 1992). Through careful preparation, the enjoyment and enthusiasm aroused by the students' visit to the science center can be transferred to the achievement of science objectives back at school.

References

Balling, J. D., & Falk, J. H. (1980). A perspective on field trips: Environmental effects on learning. *Curator, 23*, 229-240.

Balling, J. D., Falk, J. H., & Aronson, R. (undated). *Pre-trip programs: An exploration of their effects on learning from a single-visit field trip to a zoological park.* Unpublished manuscript, Smithsonian Institution, Office of Educational Research, Washington, DC.

Barrett, R. E. (1965). Field trip tips. *Science and Children, 3*(2), 19-20.

Beardsley, D. G. (1975). Helping teachers to use museums. *Curator, 18*, 192-199.

Beiers, R. J., & McRobbie, C. J. (1992). Learning in interactive science centers. *Research in Science Education, 22*, 38-44.

Bennett, E. M., & Thompson, E. (1990, April). *The exhibit interpreter: An attention focuser in science museums.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA. (ERIC Document Reproduction Service No. ED 319 616)

Birney, B. A. (1988). Criteria for successful museum and zoo visits: Children offer guidance. *Curator, 31*, 292-316.

Bitgood, S. (Ed.). (1989a). School field trips. [Special issue]. *Visitor Behavior, 4*(2).

Bitgood, S. (1989b). School field trips: An overview. *Visitor Behavior, 4*(2), 3-6.

Bitgood, S., Serrell, B., & Thompson, D. (1994). The impact of informal education on visitors to museums. In V. Crane, H. Nicholson, M. Chen & S. Bitgood (Eds.), *Informal Science Learning* (pp. 61-106). Washington, DC: Research Communications.

Blud, L. M. (1990). Social interaction and learning among family groups visiting a museum. *Museum Management and Curatorship, 9*, 43-51.

Boisvert, D. L., & Slez, B. J. (1994). The relationship between visitor characteristics and learning-associated behaviors in a science museum discovery space. *Science Education, 78*, 137-148.

Boram, R., & Marek, E. A. (1991). *The effects of free exploration from hands-on science center exhibits.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Lake Geneva, WI. (ERIC Document Reproduction Service ED 337 354)

Borun, M., Flexer, B. K., Casey, A. F., & Baum, L. R. (1983). *Planets and pulleys: Studies of class visits to science museums.* Philadelphia: Franklin Institute of Science Museum and Planetarium. (ERIC Document Reproduction Service No. ED 267 965)

Boyd, W. L. (1990). Museums as centers of learning. *Teachers College Record, 94*, 761-770.

Braverman, M. T., Yates, M. E. (1989, March). *Enhancing the educational effectiveness of zoos.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA. (ERIC Document Reproduction Service ED 306 132)

Bremer, K. B. (1992). Children's gender behavior at science museum exhibits. *Curator, 35*, 39-48.

Canizales De Andrare, R. (1990). Comparisons of learning from structured and nonstructured visits to a science exhibit. *Dissertation Abstracts International, 51*(01), 127.

Carlisle, R. W. (1985). What do school children do at a science center? *Curator, 28*, 27-33.

DeWaard, R. J., Jagmin, N., Maisto, S. A., & McNamara, P. A. (1974). Effects of using programmed cards on learning in a museum environment. *Journal of Educational Research, 67*, 457-460.

Diamond, J. (1986). The behavior of family groups in science museums. *Curator, 29*, 139-154.

Diamond, J. (1991). Prototyping interactive exhibits on rocks and minerals. *Curator, 34*, 5-17.

Diamond, J., St. John, M., Cleary, B., & Librero, D. (1987). The Exploratorium's explainers program: The long term impacts on teenagers of teaching science to the public. *Science Education, 71*, 643-656.

Dierking, L. D., & Falk, J. H. (1994). Family behavior and learning in informal settings: A review of the research. *Science Education, 78*, 57-72.

Donald, J. (1991). The measurement of learning in the museum. *Canadian Journal of Education, 16*, 371-382.

Dymond, F., Goodrum, D., & Kerr, I. (1990). *Evaluation of Scitech exhibits*. Perth, Australia: MASTEC, Western Australian College of Advanced Education.

Eason, L. P., & Linn, M. C. (1976). Evaluation of the effectiveness of participatory exhibits. *Curator, 19*, 45-61.

Erätuuli, M., & Sneider, C. (1990). The experiences of visitors in a physics discovery room. *Science Education, 74*, 481-493.

Falk, J. H. (1983a). A cross-cultural investigation of the novel field trip phenomenon: National Museum of Natural History, New Delhi. *Curator, 26*, 315-323.

Falk, J. H. (1983b). Time and behavior as predictors of learning. *Science Education, 67*, 267-276.

Falk, J. H., & Balling, J. D. (1982). The field trip milieu: Learning and behavior as a function of contextual events. *Journal of Educational Research, 76*, 22-28.

Falk, J. H., & Balling, J. D. (1979). *Setting a neglected variable in science education: Investigations into outdoor field trips*. (Final Report to the National Science Foundation SED 77-18913). (ERIC Document Reproduction Service No. ED 195 441)

Falk, J. H., & Dierking, L. D. (1992). *The museum experience*. Washington, DC: Whalesback Books.

Falk, J. H., & Dierking, L. D. (1994). Assessing the long term impact of school field trips. In J. H. Falk & L. D. Dierking (Eds.), *Proceedings of the annual meeting of the American Associations of Museums* (pp. 71-75). Seattle, Washington: American Associations of Museums.

Falk, J. H., Koran, J. J. Jr., & Dierking, L. D. (1986). The things of science: Assessing the learning potential of science museums. *Science Education, 70*, 503-508.

Falk, J. H., Koran, J. J. Jr., Dierking, L. D., & Dreblow, L. (1985). Predicting visitor behavior. *Curator, 28*, 248-257.

Falk, J. H., Martin, W., & Balling, J. D. (1978). The novel field trip phenomenon: Adjustment to novel settings interferes with task learning. *Journal of Research in Science Teaching, 15*, 127-134.

Feher, E., & Rice, K. (1985). Development of scientific concepts through the use of interactive exhibits in a museum. *Curator, 28*, 35-46.

Finson, K. D., & Enochs, L. (1987). Student attitudes toward science-technology-society resulting from a visit to a science-technology museum. *Journal of Research in Science Teaching, 24*, 593-609.

Flexer, B., & Borun, M. (1984). The impact of a class visit to a participatory science museum exhibit and a classroom science lesson. *Journal of Research in Science Teaching, 21*, 863-873.

Follette, R. L. (1987). Development of a guide for teachers to use in planning museum field trips for school groups. (Doctoral dissertation, University of Pittsburgh, 1987) *Dissertation Abstracts International, 49* (4), 711. (University Microfilms Inc. No. 8808249)

Fry, H. (1987). Worksheets as museum learning devices. *Museums Journal, 86*, 219-225.

Gennaro, E. (1981). The effectiveness of using previsit instructional materials on learning for a museum field trip experience. *Journal of Research in Science Teaching, 18*, 275-279.

Gennaro, E., Stoneberg, S. A., & Tanck, S. (1982). Chance or the prepared mind? *Journal of Museum Education, 7*(4), 16-18.

Gottfried, J. L. (1979). A naturalistic study of children's behavior in a free choice learning environment. (Doctoral dissertation, University of California, 1979). *Dissertation Abstracts International, 40* (7), 3926A. (University Microfilms Inc. No. 8000358)

Gottfried, J. L. (1980). Do children learn on school field trips? *Curator, 23*, 165-174.

Griffin, J. (1988). Learning science at specialized hands-on science centers. *The Australian Science Teachers Journal, 34*(4), 35-40.

Griffin, J. (1994, November). *Museums are educational institutions but are they always places of learning?* Paper presented at the Inaugural Museums Australia Conference, Fremantle, Western Australia.

Hawkins, D. (1965). Messing about in science. *Science and Children, 2*(5), 5-9.

Hidi, S., Soren, B., & Weiss, J. (1994, April). *Interest in science and technology*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, MI.

Hilke, D. D., & Balling, J. D. (1985). The family as a learning system: An observational study of family behavior in an information rich setting. In J. D. Balling, D. D. Hilke, J. D. Liversidge, E. A. Cornell & N. S. Perry (Eds.), Role of the family in the promotion of science literacy. (Final Report for National Science Foundation Grant No. SED-811-2927, pp. 60-104). Gloucester Point, VA: Chesapeake Research Consortium, Inc.

Hoke, M. W. (1991). Field-trip tips – A baker's dozen. *Science and Children, 28*(7), 20-21.

Javlekar, V. D. (1989). Learning scientific concepts in science centers. In S. Bitgood (Ed.), *Proceedings of the 1989 Visitor Studies Conference, 2*, 168-179.

Koran, J. J., Jr., & Baker, S. D. (1979). Evaluating the effectiveness of field experiences. In M. B. Rowe (Ed.), *What research says to the science teacher* (Vol. 2, pp. 50-67). Washington, DC: National Science Teachers Association.

Koran, J. J., Jr., & Ellis, J. (1991). Research in informal settings: Some reflections on designs and methodology. *ILVS Review, 2*, 67-86.

Koran, J. J., Jr., Lehman, J. R., Shafer, L. D., & Koran, M. L. (1983). The relative effects of pre- and postattention directing devices on learning from a "walk-through" museum exhibit. *Journal of Research in Science Teaching, 20*, 341-346.

Koran, J. J., Jr., & Koran, M. L. (1986). A proposed framework for exploring museum education research. *Journal of Museum Education, 11*, 12-16.

Koran, J. J., Jr., Koran, M. L., & Longino, S. (1986). The relationship of age, sex, attention, and holding power with two types of science exhibits. *Curator, 29*, 227-235.

Koran, J. J., Jr., Longino, S., & Shafer, L. D. (1983). A framework for conceptualizing research in natural history museums and science centers. *Journal of Research in Science Teaching, 20*, 325-339.

Krepel, W. J., & DuVall, C. R. (1981). *Field trips: A guide for planning and conducting educational experiences*. Washington, DC: National Education Association. (ERIC Document Reproduction Service No. ED 205 526)

Kubota, C. A., & Olstad, R. G. (1991). Effects of novelty-reducing preparation on exploratory behavior and cognitive learning in a science museum setting. *Journal of Research in Science Teaching, 28*, 225-234.

Lam-Kan, K. S. (1985). *The contributions of enrichment activities towards science interest and science achievement*. Unpublished master's thesis, National University of Singapore.

Lehman, J. R., & Lehman, K. M. (1984). The relative effects of experimenter and subject generated questions on learning from museum case exhibits. *Journal of Research in Science Teaching, 21*, 931-935.

Linn, M. C. (1980). Free-choice experiences: How do they help children learn? *Journal of Research in Science Teaching, 14*, 237-248.

Lucas, A. M. (1983). Scientific literacy and informal learning. *Studies in Science Education, 10*, 1-36.

Lucas, A. M. (1985). Investigating how science is learned from informal sources. In M. B. Dynan & B. J. Fraser (Eds.), *Informal learning of science*. Perth, Australia: Western Australian Institute of Technology.

Lucas, A. M., McManus, P., & Thomas, G. (1986). Investigating learning from informal sources: Listening to conversations and observing play in science museums. *European Journal of Science Education, 8*, 341-352.

Mallon, G. L., & Bruce, M. H. (1982). Student achievement and attitudes in astronomy: An experimental comparison of two planetarium programs. *Journal of Research in Science Teaching, 19*, 53-61.

Martin, M., Brown, S., & Russell, T. (1991). A study of child-adult interaction at a natural history centre. *Studies in Educational Evaluation, 17*, 355-369.

Mason, J. L. (1980). Annotated bibliography of field trip research. *School Science and Mathematics, 80*, 155-166.

McManus, P. M. (1985). Worksheet-induced behavior in the British Museum. *Journal of Biological Education, 19*, 237-242.

McManus, P. M. (1987). It's the company you keep: The social determination of learning-related behavior in a science museum. *International Journal of Museum Management and Curatorship, 6*, 263-270.

McManus, P. M. (1988). Good companions: More on the social determination of learning-related behavior in a science museum. *International Journal of Museum Management and Curatorship, 7*, 37-44.

McManus, P. M. (1989). Oh, yes, they do: How museum visitors read labels and interact with exhibit items. *Curator, 32*, 174-189.

McManus, P. M. (1993a). Memories as indicators of the impact of museum visits. *Museum Management and Curatorship, 12*, 367-380.

McManus, P. M. (1993b). Thinking about the visitor's thinking. In S. Bicknell & G. Farmelo (Eds.), *Museum visitor in the 90's*. London: Science Museum.

McManus, P. M. (1994). Families in museums. In R. Miles & L. Zavala (Eds.), *Towards the museum of the future: New European perspectives*. London: Routledge.

Melton, A. W., Feldman, N. G., & Mason, C. W. (1988). *Experimental studies of the education of children in a museum of science*. Washington, DC: American Association of Museums. (Original work published 1936)

Morrissey, K. (1993). Museum on a disk [Computer software]. East Lansing, MI: Michigan State University Museum.

Parsons, C., & Muhs, K. (1994, July). *Field trips and parent chaperones: A study of self-guided school groups and the Monterey Bay aquarium*. Paper presented at the Visitors Studies Conference, Raleigh, NC.

Pollock, S. (1983). An inside view of education at the Natural History Museum in London. *Journal of Biological Education, 17*, 119-122.

Prather, J. P. (1989). Review of the value of field trips in science instruction. *Journal of Elementary Science Education, 1*(1), 10-11.

Price, S., & Hein, G. E. (1991). More than a field trip: Science programs for elementary school groups at museums. *International Journal of Science Education, 13*, 505-519.

Ramey-Gassert, L., Walberg, H. J., III, & Walberg, H. J. (1994). Reexamining connections: Museums as science learning environments. *Science Education, 78*, 345-363.

Rennie, L. J. (in press). Measuring affective outcomes form a visit to a science education centre. *Research in Science Education*.

Rennie, L. J. (1993). Measuring cognitive outcomes from interactive science centres. In R. Schibeci (Ed.), *Proceedings of the Eighteenth Annual Conference of the Western Australian Science Education Association* (pp. 29-39). Perth, Australia: Murdoch University.

Rennie, L. J., & Elliott, M. T. (1991). What students do at CSIROSEC. In M. W. Hackling (Ed.), *Proceedings of the Sixteenth Annual Conference of the Science Education Association of Western Australia* (pp. 117-125). Edith Cowan University, Perth: Edith Cowan University, Dept. of Science Education.

Sakofs, M. S. (1984). Optimising the educational impact of a museum tour. *Curator, 27*, 135-140.

Schibeci, R. (1992). *Evaluation of the educational benefit of the 'Sports Works' exhibition at Scitech Discovery Center Final report*. Perth, Australia: Scitech Discovery Center.

Screven, C. G. (1984). Educational evaluation and research in museums and public exhibits: A bibliography. *Curator, 27*, 147-165.

Screven, C. G. (1986). Exhibitions and information centers: Some principles and approaches. *Curator, 29*, 109-137.

Semper, R. J. (1990, November). Science museums as environments for learning. *Physics Today*, 2-8.

Semper, R., Diamond, J., & St. John, M. (1982). Use of interactive exhibits in college physics teaching. *American Journal of Physics, 50*, 425-430.

Shepley, A. V. (1974). Towards more effective field teaching. *School Science Review, 55*(193), 817-822.

Sneider, C. I., Eason, L. P., & Friedman, A. J. (1979). Summative evaluation of a participatory science exhibit. *Science Education, 63*, 25-36.

Sorrentino, A. V., & Bell, P. E. (1970). A comparison of attributed values with empirically determined values of secondary school science field trips. *Science Education, 54*, 233-236.

Stankiewicz, J. J. (1984). The effects of an advanced organizer on the ability of randomly selected groups of seventh and eighth grade science students to recall. (Doctoral dissertation, Temple University, 1984). *Dissertation Abstracts International, 45* (1), 143A. (University Microfilms Inc. No. 8410162)

Stevenson, J. (1991). The long-term impact of interactive exhibits. *International Journal of Science Education, 13,* 521-531.

Stronck, D. R. (1983). The comparative effect of different museum tours on children's attitudes and learning. *Journal of Research in Science Teaching, 20,* 283-290.

Talisayon, V. M., & Talisayon, S. D. (1987). *Evaluation of short-term and long-term impacts of exhibits at the Singapore Science Center.* (Available from Singapore Science Center, Jurong, Singapore)

Tuckey, C. J. (1992). Schoolchildren's reactions to an interactive science center. *Curator, 35,* 28-38.

Tulley, A., & Lucas, A. M. (1991). Interacting with a science museum exhibit: Vicarious and direct experience and subsequent understanding. *International Journal of Science Education, 13,* 533-542.

Wolins, I. S., Jensen, N., & Ulzheimer, R. (1992). Children's memories of museum field trips: A qualitative study. *Journal of Museum Education, 17*(2), 17-27.

Wright, E. (1980). Analysis of the effect of a museum experience on the biology achievement of sixth graders. *Journal of Research in Science Teaching, 17,* 99-104.