Bridging the Gap Between Formal and Informal Science Learning

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INTRODUCTION

In the teaching of school science, curriculum material and instructional strategies ideally should be tailored to the abilities and aptitudes of different types of learners. The overall objective should be to create learning environments which allow students to interact physically and intellectually with instructional materials through 'hands-on' experimentation and 'minds-on' reflection. Effort should be made to provide materials and instruction that give reality and concreteness to scientific concepts. Ideally, teachers should use a variety of instructional strategies and learning materials with the aim of increasing the impact and the effectiveness of their teaching (Tobin, Carie & Bettencourt 1988; Hofstein & Walberg 1994). The importance of varying instructional techniques has been investigated recently (Hofstein & Kempa 1985; Kempa & Diaz 1990a, 1990b). It is suggested that a strong relationship exists between a student's motivational characteristics and his or her preference for particular modes of instruction.

This finding is important and should be taken into consideration in the design and implementation of instructional techniques and content. In practice, it is difficult to respond appropriately to students' motivational characteristics and preferred modes of instruction. Informal science learning environments (e.g., science museums, zoos and outdoor settings; science youth programs; science media) could be utilized to maximize this end. Therefore, it would be useful if science educators would consciously utilize (1) a wide repertoire of instructional strategies in their work with learners in schools, as well as (2) a wide range of out-of-school environments which foster science learning.

Human beings learn science from a variety of sources, in a variety of settings, and for a variety of reasons. For the sake of simplicity, we assume that the two complementary contexts for science learning are formal and informal learning. In this article we focus our attention on informal science learning and examine how it might be better integrated into formal science learning. We first define this term and consider why assessing such learning would be valuable. After presenting commonly-asked evaluation and research questions, we relate them to appropriate evaluation and research methods. Finally, we present and integrate findings from selected research and evaluation studies of informal science learning in several settings: school-based field trips, student projects, community-based science youth programs, casual visits to 'free-choice learning environments' such as museums and zoos (including the design of educational exhibits), and the press and electronic media. We conclude that informal science learning experiences can make significant contributions in providing appropriate learning opportunities to diverse learners and in motivating them to learn science, both within and outside of schools.

DEFINITION OF INFORMAL SCIENCE LEARNING

There is no clear agreement in the literature regarding the definition of informal science learning. Part of the problem is that such learning can take place in many environments, e.g., natural history parks, geological sites, zoos, botanical gardens, industry, science museums and nature centres. The major difficulty in defining informal science learning is determining whether or not informal science learning can take place within formal settings. In other words, does the term have distinct, clear-cut attributes of its own (in which case it may occur in formal as well as informal settings) or must this term be understood as necessarily contrasted with formal learning (in which case it cannot occur in formal settings)? We can identify two approaches to this definition problem.

The first type of definition of informal learning draws a sharp dichotomy between informal and formal learning. As an example, consider the following comparison between 'informal learning' via field trips and 'formal learning' via school (Wellington 1991). The problem with this approach is that it is overly simplistic. For example, visits to museums can be voluntary or compulsory, structured or unstructured, sequenced or unsequenced, etc.

TABLE 1

Features of Formal and Informal Science Learning

Informal learning - field trips	Formal learning - school
Voluntary	Compulsory
Unstructured	Structured
Unsequenced	Sequenced
Nonassessed	Assessed
Unevaluated	Evaluated
Open-ended	Close-ended
Learner-led	Teacher-led
Learner-centered	Teacher-centered
Out-of-school context	Classroom context
Non-curriculum-based	Curriculum-based
Many unintended outcomes	Fewer unintended outcomes
Less directly measurable outcomes	Empirically measured outcomes
Social intercourse	Solitary work
Nondirected or learner directed	Teacher directed

Modified from Wellington (1991, p. 365), based on Rommey and Gassert (1994).

In contrast, the following definition, taken from a comprehensive research review of informal science learning (Crane Nicholson & Chen 1994), has taken a 'hybrid approach', which includes formal and informal learning. The term is first defined in contrast to formal learning:

> 'Informal learning refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation as part of a credited school experience. Informal learning experiences may be structured to meet a stated set of objectives and may influence attitudes, convey information, and/or change behavior.' (p. 3)

However, the same definition continues by allowing informal learning to include formal learning, under certain conditions:

> 'Informal learning activities also may serve as a supplement to formal learning or even be used in schools or by teachers, but their distinguishing characteristic is that they were developed for out-of-school learning in competition with other less challenging uses of time. . . . There are many informal learning media including exhibits and demonstrations in museums, aquariums, and zoos; television, radio, and community-based programs, books, magazines, hobbies, and newspapers.' (p. 3)

These two different types of definition highlight the importance of understanding what we mean by formal and informal science learning. In this article, we have adopted the 'hybrid' definition, namely that informal learning experiences can occur in formal learning environments (e.g., schools) as well as informal learning environments (e.g., museums, zoos).

METHODOLOGICAL ISSUES

We take the view that the research methods to be employed in a given educational study need to be chosen on the basis of (a) the context of the setting, (b) the intended readers of the study, and (c) the specific questions to be investigated. This 'problem-driven' approach differs significantly from a 'method-driven' approach, in which the evaluation or research methods are given from the outset, and appropriate problems are selected for investigation.

While it may be simplistic to categorize evaluation and research studies in science education as 'problem-driven' or 'method-driven', the distinction is useful to underscore a practical problem: the same evaluation and research methods used to investigate formal classroom lessons may not be appropriate methods to investigate school field trips, casual visits to a museum, community-based science youth programs and science television programs. In the words of Lucas, McManus & Thomas, (1986):

> 'The major difference between classical studies on learning and learning from informal settings is that the context of informal learning must be preserved if the results are to have validity. Classrooms are places where interactions between teachers and pupils are expected, and the replacements of the teacher by the researchers will have much less effect on the validity of the conclusions than the introduction of a researcher into the interaction between museum visits and the exhibit'. (p. 5)

Why conduct research of informal learning? Based on the literature reviewed in this article, it appears that such research serves three purposes:

Practical: Informal Research Goals. This goal is aimed at individuals who work in informal science learning environments; these individuals are interested in knowing how to design and evaluate educational programs and exhibits which interest and hold the attention of the relevant 'consumers', and which impart meaningful science-related content and attitudes.

Practical: Formal Research Goals. This goal is aimed at individuals who work primarily in the context of the formal school environment and who are interested in knowing how to adapt and evaluate informal science learning methods (e.g., field trips) within the formal school environment.

Theoretical Understanding. This goal is aimed at finding out how and under what conditions learners learn science within informal science learning environments.

The questions which are of interest to each of these audiences are varied. The following questions, which can be applied to each of the informal science learning settings presented in this paper, are representative of those which interest these three overlapping audiences. Clearly, in order to bridge the gap from research to practice, all of them are relevant for research and evaluation.

> What do children, adults and family groups do and find interesting in (field trips, casual visits, science projects, community-based science programs, the science media)?
> What do children, adults and family groups learn from (field trips, casual visits, etc.)?
> What are the factors that influence what and how much they do and learn?
> How do (field trips, casual visits, etc.) influence children's perceptions and attitudes about science?
> How could (field trips, casual visits, etc.) be designed and implemented to better achieve important learning goals?
> How might (field trips, casual visits, etc.) be integrated into the formal science curriculum?

In a 'problem-driven' approach, the researchers must adopt and adapt appropriate research methods to provide the data needed to answer their research questions. In other words, the methods chosen for use in evaluation and research studies must be appropriate not only to the chosen setting but to the research questions as well.

A wide variety of methods has been employed in such studies. These methods have been adapted from various research traditions, such as the physical sciences, (e.g., controlled experiments), natural history (e.g., naturalistic observations and studies), ecology (e.g., correlational analysis of different factors in a complex system), the anthropological sciences (e.g., participant observation, in-depth interviews, content analysis), the social sciences (focus-group interviews, questionnaires), the cognitive sciences (e.g., the clinical interview, task-analysis, protocol analysis, etc.), animal behavior (e.g. quantitative as well as qualitative observational studies, tracking, unobtrusive measures), as well as educational research.

REVIEW OF RESEARCH FINDINGS OF INFORMAL SCIENCE LEARNING

Our discussion about the methodological issues leads us to recognize the importance of distinguishing between two contexts of learning: the compulsory context and the free-choice context. However, in accordance with our 'hybrid' definition of informal learning, we view these two contexts as existing on a continuum. In the following discussion, we present five learning modes which exist on this continuum (from compulsory to free-choice): (1) school-based field trips, (2) student projects, (3) community-based science youth programs, (4) casual visits to museums and zoos, and (5) the press and electronic media.

1. School-Based Field Trips

On the basis of the suggested hybrid approach to informal learning, we adopted the following definition of field trips (Krepel and Durall, 1981):

> A trip arranged by school and undertaken for educational purposes in which students go to a place where the materials of instruction may be observed and studied directly in their functional setting. (p. 7)

Such visits are standard practice in science education and much has been written concerning their educational desirability (e.g., Koran &

Baker 1979). In contrast to the conventional environment of the classroom, field trips take place in a more open, flexible and democratic environment. The field trip (e.g., museum, zoo, science centre and geological field trip) has a potential for providing for instructional techniques that are more 'student centered', in which participants usually are able to move around at their own pace and to explore and experiment on their own (Feher, 1990). Furthermore, the field trip can provide students with concrete experiences, allowing them to interact physically and to manipulate objects (e.g., biological specimens and physical phenomena) which are usually unavailable in the formal science classroom.

Surprisingly, little research evidence regarding field trips is available (Falk 1983a; Orion & Hofstein 1994). We present a summary of this research in terms of methodological issues, cognitive outcomes, affective outcomes, and an organizational principle known as the 'novelty factor'.

Methodological Issues

Falk, Koran & Dierking (1986) wrote that 'it is probably safe to conclude based on anecdotal and increasingly empirical evidence that informal science settings are extremely important learning situations for conveying certain kinds of cognitive and affective science information to students' (p. 507). But there are several methodological issues in conducting evaluation and research regarding the educational effectiveness of field trips: (1) definition of terms, (2) logistical problems, (3) teacher confidence, and (4) identification of the relevant variables.

The first methodological issue is defining what is meant by 'field trip'. A field trip may be part of a day, a day long, or a weekend long excursion; it can be a simple guided tour to an area of interest, or it may include the conducting of an active research oriented (inquiry type) field project (Beiersdorfer & Davis 1994). The field trip could be educationally ineffective, it may be just moving a classroom lecture to the outdoors, or it may be extremely effective when the tasks are clear and structured.

A second methodological issue is logistics. Field trips are most difficult to implement and are often expensive. As a result, they are often seen (by teachers and administrators) as disruptions to the normal school program.

A third methodological difficulty is that many teachers do not feel confident enough to lead outdoor activities since they lack background knowledge as well as training in field techniques (Yaakobi 1981); this is due to the fact that most preservice and inservice programs for science teachers tend to avoid training teachers in this area. In reviewing the literature published since 1930, Mason (1980) found 43 empirical studies that dealt with the cognitive and affective outcomes of outdoor education. Most of these studies compared field trips to another teaching method. Several articles reported that teachers tended to avoid outdoor experiences because of their unfamiliarity with the philosophy and logistics of field trips (Fido & Gayford 1982; McKenzie *et al.* 1986). Hickman (1976) and Mirka (1980) found that teachers avoid outdoor activities because of a lack of curriculum material (for both teacher and student) relevant to this type of activity.

A fourth methodological difficulty relates to identifying, isolating, and controlling the relevant variables which impact on the field trip. McClafferty & Rennie (1992), on reviewing 39 studies conducted between 1974-1992, found that only a few studies investigated factors that influence students' ability to learn in the outdoor environment and that only limited information exists on the conditions for an effective implementation of such experiences.

Cognitive Outcomes

A review of six studies (summarized by Falk 1983a) suggests that significant cognitive learning can and frequently does occur during field trips. He also reported that information acquired on a field trip may be remembered for a long time. This is an important addition to the notion that visits to museums, zoos and science centers are enjoyable and result in long-lasting positive memories. Several studies investigated the learning of certain concepts in informal science settings. For example, a study utilizing a phenomenographic approach to investigate the amount of learning in an interactive science event regarding the concept of *sound*, was conducted in Australia by Beiers & McRobbie (1992). In the preparatory phase, before visiting the center, students underwent a structured interview and a concept map exercise. After the visit, students were asked to draw a concept map regarding the concept *sound.*

In the U.S.A., a series of studies (Rice & Feher 1987; Feher & Rice 1988; Feher 1990), that were based on behavioral psychology, suggested that meaningful learning could occur provided that the exhibits are interactive in nature. The work by Feher & Rice (1988) focused on the concept *light* (i.e. vision, image formation, shadow formation and color). The methodology that the researchers adopted was a 'field version' of the Piagetian task-based clinical interviews. In this method, the interviewer engages the child in a dialogue using questions from a protocol.

In Singapore, two studies were conducted by Lam-Kan 1985, and Finson & Enochs 1987 in the Singapore Science Center. In order to assess the attainment of science concepts, the *co-operation science test* was used. It was found that by and large, students who interacted with the exhibit at the center outperformed students who had no experience with the exhibition regarding the concepts that underlined the exhibits.

The learning opportunities provided by informal science settings are difficult to replicate in formal traditional learning in schools. Studies which compare learning science in schools and in museums are rare. McClafferty & Rennie (1992) reported on a study conducted by Javlekar (1989) in the Nehru Science Center in India. In this study, 7th grade students (age 12-13) were involved. The measures used were: (a) a cognitive aspects inventory of the exhibits; (b) an exhibit evaluation instrument: and (c) teacher interviews. Javlekar found that students who visited the exhibits out-performed the control group in the understanding of scientific concepts that underlined the exhibits. He also found that interactive techniques are the best approach to achieve a better understanding of concepts underlying the exhibits in the science center.

Affective Outcomes

The question can be asked whether field trips are effective in attaining goals beyond knowledge. Several studies have revealed the importance of the outdoors in the development and improvement of affective characteristics in the student (Koran & Baker 1979; Kern & Carpenter 1986). Falk (1983a), on reviewing five studies conducted in informal settings, e.g., visits to museums, zoos, geological sites, etc., found that in general, they resulted in enjoyable and long-lasting memories. The issue of 'structured' or 'unstructured' exhibits was addressed by Stronck (1983) and Wright (1980). Wright (1980) found that students' attitudes toward the exhibits when they were structured were significantly better than towards those that were 'unstructured'. Dyamond, Goodrum & Kerr (1991) assessed students and visitors with an instrument to ascertain attitude in several science exhibits in science centers. Their findings indicated that the attitudes towards science of grade 6-8 (age 11-13) students were enhanced by these visits.

Koran & Baker (1979) reviewed many comparative studies conducted between 1950-1976. In these studies, outcomes of field trips were compared with other instructional techniques. Most of these studies (e.g., Bennett 1965; Brady 1972; Reed 1972) resulted in no significant differences between the two approaches regarding affective outcomes.

A review of the literature shows that, in most of the studies, student attitudes towards informal activities formed part of a more comprehensive study in which both cognitive and affective outcomes were assessed (e.g. Orion & Hofstein 1994). Only a small number of studies were specifically designed to assess affective variables only. For example, a study aimed at answering the question whether field trips will influence scientific attitudes was conducted by Harvey (1951; reported by Koran & Baker 1974). In this study, an experimental group underwent a series of geological field trips while a control group discussed ecological concepts in a regular classroom. Those who underwent the field trips out-performed the control group on the standard *Caldwil & Curtis Scientific Attitude Test*. This effect was attained even after short field visits. This result may suggest that well-prepared and well-designed field trips could have a significant impact on students' attitudes. Support for these findings was obtained 40 years later by Orion & Hofstein (1991) who developed a Likert-type scale aimed at measuring student attitudes towards various components of the field trip. (A Likert scale measures the degree of agreement with given statements). Their analysis revealed that the attitude towards the field trip was not unidimensional and consisted of five unique dimensions: the field trip as an 'instructional tool', as 'individualized learning', 'social events', 'adventure event' and 'environmental aspect'.

The 'Novelty Factor'

Several studies (Falk Martin & Balling 1978; Martin Falk & Balling 1981; Falk & Balling 1982; Falk 1983a; Kubota & Olstad 1991) focused on the psychological aspect of the field trip. These studies demonstrated that the ability of students to conduct cognitive tasks during a field trip depends on their familiarity with the field trip setting. They called this variable *environmental novelty.* Falk Martin & Balling (1978) suggested that: 'The novel field situations produce an adaptation or adjustment process on the part of the student which direct their behavior toward the environment and away from the structured learning activities' (p. 128). Kubota & Olstad (1991) showed that children, after visiting informal learning settings, demonstrated a considerable amount of non-exhibit related learning if the setting was novel to them. Kagan & Fasan (1988) (also supported by Falk *et al.* 1978) suggested that an unfamiliar environment may cause anxiety in a child which, as a result, may cause inhibition of achievement and standard learning. Falk & Balling (1980), Kubota & Olstad (1991), and Orion & Hofstein (1994) explained ways to reduce this 'novelty factor'.

The study by Kubota & Olstad (1991) involved 6th grade children (age 11). An experimental group received vicarious exposure (slides) before the actual visit to the museum aiming at reducing the novelty of a field trip while a 'placebo' group got an informative but not a novelty reducing treatment. Following these treatments, the two groups were taken to the science museum. The children were observed using video cameras. The videos were qualitatively analyzed. The results have clearly indicated that the novelty reducing preparation resulted increased on-task exploratory behavior and greater learning in boys but no effects were observed with girls. Kubota & Olstad (1991) explained this finding by arguing that since most of the exhibits were physics-oriented, girls demonstrated only limited interest.

Orion & Hofstein (1994) suggest that a 'novelty environment' consists of three factors: *the cognitive novelty*, which depends on the concepts and skills that students are asked to deal with during the field trip; *the geographical novelty*, which reflects the acquaintance of the students with the field trip area; and *the psychological novelty,* i.e. the students' previous experiences with the outdoors as a social adventurous event (rather than a learning activity). They found that proper preparation prior to the field trip and the proper placement of the field trip in the science curriculum helped in remedying the novelty factor. It was suggested that preparation for the field trip, addressing all three novelty factors mentioned above, can maximize familiarity and thus facilitate meaningful learning during the field trip.

In summary, it is suggested that the knowledge regarding novelty environment (suggested by Falk, Martin & Balling 1978) and the novelty factor (suggested by Orion & Hofstein 1994) have important implications for the learning conditions of field trips and other informal science learning events.

2. Student Projects

Student science projects involving individual investigation are well-known student learning activities. The principles underlying the idea of student research projects can be applied to a wide range of curricular methodologies. A project may be an individual or a small group effort aiming at understanding in depth a given question in the sciences. In a research project, students can follow their interests, and develop themselves as social-minded, self-governing persons exhibiting self-respect, self-direction, initiative, self-criticism and persistence (Kilpatrick 1951). The intended goal of the independent research project is to develop a more independent and autonomous learner. The research literature is limited regarding information on the assessment of such research projects. In Israel, students choose an independent ecology project called *Biotop* in the context of the biology curriculum (Tamir & Friedler 1994). The project is usually related to structure, function and interaction of plants and animals in a particular ecosystem. Projects are carried out outdoors, sometimes using the school laboratory as well (Bakshi & Lazarowitz 1982). In addition, Israeli high school students are invited to conduct scientific research under the assistance of practicing research scientists, as part of their formal education. One of the challenges regarding this work is the proper training of teachers to support such research (Rosenfeld, Pundak & Luria, 1995).

Similarly, a geological project called *Geotop*, which takes place in both geological sites and laboratory, was developed in the ecological project. The main objectives of the *Geotop* are (based on Orion 1994):

> The application of knowledge and skills learned in the classroom, laboratory and outdoors.
> Learning and exercising scientific investigation processes.
> The development of individual study skills.
> Enhancing students' intellectual curiosity.
> Development of positive attitudes towards the *Geotop*.

Tytler (1992) in Australia explored the value of independent research projects. His study was conducted among students who participated in a Science Fair in Australia (Victoria Science Talent Search). His population consisted of 365 prize winners, who were administered a questionnaire. The questionnaire probed the students' ideas for their projects and the sources of help they obtained during the project. Interestingly enough, the most common answer was '. . . it came out of the top of my head.' In order to obtain more comprehensive information, a naturalistic investigation was conducted in which a selected number of students were interviewed. Despite the wide range of topics, some attributes were evident in all the cases:

> Interest and motivation, rather than intellectual capabilities, are the key ingredients for accomplishing such projects.
> The home environment is an important ingredient in cultivating and guiding interest and in accomplishing such a project.
> Students demonstrated commitment while undertaking the independent research projects.
> Self-reliance was shown in the pursuit of background knowledge and in the arrangement of experimental procedures or the design of innovations.

In conclusion, one of the biggest problems regarding student projects is the difficulty of reliable assessment. This is because projects vary in difficulty, scores tend to have low reliability (Boud *et al.* 1986; Clemenson 1977) and there is a lack of valid criteria for assessment. On the other hand, such projects have a very high validity and provide significant learning opportunities for students (Woolnough, 1994).

3. Community-Based Science Youth Programs

Extracurricular science clubs can be found all over the world. These clubs exist in such centres as the British Association of Young Scientists (BAYS) in the UK (Lucas 1983), the Youth Activities Section at the Weizmann Institute of Science in Israel (Eylon, Hofstein, Maoz & Rishpon 1985), and organizations such as nature reserves and parks, which host meetings of youth clubs for scientific purposes. (A more comprehensive list of science activities is described by Lucas (1983)).

On the whole, little research has been conducted in such settings and the information regarding their impact and educational effectiveness is rather limited. Eylon, Hofstein, Maoz & Rishpon (1985) conducted a study at the Youth Activities Section in the Weizmann Institute of Science in Israel aimed at finding reasons why students enrol in extracurricular science courses, their scientific ability and some of the affective outcomes of these courses. Using the *Test of Enquiry Skills* (TOES) developed by Fraser (1979), it was found that students who enrolled in such out-of-school courses differ from the formal school population in their scientific thinking, i.e., they out-performed a control school group on all the skills measured by TOES. A standard semantic differential questionnaire (Osgood, Suci & Tenenbaum, 1975) was used to measure the science club students' attitudes towards the concepts '*science*' and '*school science*'. It was found that student attitudes towards *school science* are significantly less positive than their attitudes towards *science*. Factor analytic investigation conducted on the semantic differential scales indicated that students enrolling in science clubs perceive '*science*' and '*school science*' differently. Thus, it is suggested that science clubs could provide an important addition to scientific literacy for students who are interested in a science environment beyond school science. These students are more inquiry-oriented, and they prefer activities which are more student-centered (rather than teacher-centered). It seemed that for some high-ability students, science clubs can provide an important opportunity to meet their needs. Support for the notion that science material is used differently by school teachers who tie the material directly to the school curriculum and by science club leaders who emphasize the 'fun' aspect of the same activities, was presented by Yaakobi (1981).

4. Casual Visits to Museums and Zoos

The caveat stated above that the context of informal learning must be preserved if the results of evaluation and research studies are to have validity (Lucas, McManus & Thomas 1986), is especially relevant when studying casual visits to informal learning settings, such as science museums, zoos, botanical gardens, and outdoor parks. These settings, when seen from the point of view of casual visitors, can be defined as 'free-choice learning environments' (Laetsch, Diamond, Gottfried & Rosenfeld 1979). The history of research in these settings is long and varied, though such efforts have not been well-represented in the traditional science education literature (Bitgood, Paterson & Benefield 1988; Diamond 1992; St. John 1992).

One of the most common findings of casual visits is that they are often framed as social experiences that encourage group learning. Informal settings such as science museums and zoos are popular largely because many of the activities that take place there are socially-mediated and involve social-groups. (Orion & Hofstein 1991; Diamond 1986; Rosenfeld & Terkel 1982). This finding has promoted numerous studies of family groups, which constitute a major proportion of casual visitors to settings which enhance informal science learning (Kropf 1992; Diamond 1982; Laetsch, Diamond, Gottfried & Rosenfeld 1980).

Another common finding relates to the direct relationship between the interactivity level of an exhibit and the time spent visiting it (Bitgood *et al.* 1988; Rosenfeld 1980). Since time spent at exhibits can be used as a predictor of learning (Falk 1983), exhibit designers at science museums generally try to create exhibits with a high level of interactivity.

It is interesting to note that a great deal of exploratory behavior occurs within these 'free-choice' science learning settings. This behavior was investigated by Gottfried (1979) who studied the open-ended exploratory behavior of elementary-school students to a science center's 'Biology Room,' and derived a general model for 'free-choice, exploratory behavior.' This study and others like it (e.g. Diamond, 1986; Rosenfeld, 1980, Rosenfeld, 1982) can be applied to design effective exhibits for these types of learning settings.

The Educational Design of Exhibits

The conception and design of exhibits in settings such as science and technology centers, zoos, botanical gardens and geological sites play an important role in the educational effectiveness of such informal settings (Madden 1985). Formative exhibit evaluations, based on visitor participation, can lead to the improved educational design of such exhibits (McNamara 1987; Borun 1989; Oppenheimer 1986). Research studies have also been used to investigate the relationship between exhibit characteristics and learning-associated behaviors (Boisvert & Slez, 1995).

Studies that focused on the variables that increase the educational effectiveness of educational exhibits have shown that:

Participatory exhibits attract more attention (Koran, Koran & Longino 1986), and hold the attention of visitors longer (Boisvert & Slez, 1995; Rosenfeld, 1982; Gottfried, 1979) in comparison with non-participatory exhibits.

The amount of time spent at an exhibit is positively related to learning. Longer visits can be encouraged by providing objects for manipulation (Falk 1983b).

Most students do not learn from exhibit labels. Objects, specimens and animals at an exhibit and information and guidance by a docent becomes the predominant instructional method in the field trip (Falk, Koran & Dierking 1986). Yet the improvement of a label's text can improve the learning impact (Falk, Koran & Dierking 1986).

Computers used in exhibits attract young students (Screven 1990).

Feher (1990) suggested that the exhibits should be designed as teaching/learning devices and should consist of four distinguishable levels:

Experiencing. The exhibit shows the user that certain phenomena occur in nature.

Exploring. The users discover new features of the phenomena by interacting and manipulating with the object.

Explaining. This is a conceptual level that deals with cognitive issues (mental models).

Expanding. This involves the user with the generalization of ideas through the involvement of other related exhibits.

Fehr suggested that these levels may be used as a taxonomy for the preparation of both paper and pencil (written) as well as observational measures aimed at assessing the educational effectiveness of a certain exhibit in museums or informal settings.

Bitgood, Paterson & Benefield (1988) conducted a study of 13 zoos around the US, in order to identify patterns that suggest general design principles. They measured the time spent near each of the zoo stations. They found that much time is spent near certain animals, big animals and infants. Less time is spent near places where visibility is limited and/or where visitors had to compete for visibility. Rosenfeld (1979, 1980, 1982) studied family groups visiting a metropolitan zoo and a interactive mini-zoo. On the basis of his findings, a number of design guidelines were proposed and have been implemented (e.g. animal exhibits should be enhanced to promote interactions between the family visitors and the animals, via educational exhibits and activities which invite visitors to compare themselves with the animals).

5. Press and Electronic Media

The press and electronic media carry great potential for informal science learning. This conclusion is based on the notion that life-long learning largely depends on stimulation and encouragement which originates outside the formal school system. In this respect, the press and television play an important role. The last decade has seen a tremendous growth in the distribution of science videos, cable television, CD-ROM, video discs, live computer broadcasts and the internet. All these play an important role in providing scientific literacy beyond the formal education setting. Unfortunately, however, there is still a lack of substantial research-based evidence regarding the educational effectiveness of the media and its influence on students' scientific literacy. Chen (1994) summarized the reasons for this:

> Such research is complex and difficult to design. The television stimulus is complex and there is a lack of simple assessment categories and schemes: also, the sample is usually very diverse (regarding age, interests and backgrounds).
> The complexity of the home-viewing environment. The audience does not always understand the scientific concepts the way which was intended by the producer. Thus, addressing research questions regarding long-term learning is rather complex.
> Science in the media is a result of the interpretation and filtration of journalists, audio-recorders and/or TV and video producers. Thus, the 'picture' we get is not always the objective one but an interpretive version (Wellington 1990, 1991).
> Limited funding exists for assessment and evaluation in this area.

Despite these limitations, there is some evidence (Lucas, 1985) that the media do have an impact. For example, in the area of environmental issues, there is evidence showing that 16 year old students obtain their knowledge of the environment from both electronic and written media rather than from formal schooling (Lucas, 1983). Fortner & Teafes (1983) found that knowledge of marine biology in 10th grade (age 15-16) students was positively correlated with reading and recall of National Geographic Magazine articles and of viewing and recall of Jacques Cousteau TV Specials.

From the limited amount of research based information, it is seen that well-produced television programs have the potential to enhance scientific knowledge.

SUMMARY

We began this article with a discussion of the importance of motivation and varying instructional techniques in school learning. It was suggested that a strong relationship exists between a student's motivational characteristics and his or her preference for various instructional techniques.

We have presented evidence from the research literature that informal science experiences — in school-based field trips, student projects, community-based science youth programs, casual visits to informal learning settings, and the press and electronic media — can be effectively used to advance science learning.

Our hybrid definition of informal learning highlights an important distinction between learning contexts and learning methods. As described above, we recognize a continuum of learning contexts, from the more compulsory to the more free-choice contexts. In the past, there was a strong linkage between learning contexts and methods; for example, it was assumed that the compulsory school context was tightly linked with formal learning methods, while the free-choice (out-of-school) context was linked with informal learning methods. We suggest that this linkage is at best artificial and at worst harmful to the pedagogy of science teaching and learning. It is artificial because a person's knowledge of science cannot be limited to what is learned in schools, and it can be harmful by limiting the types of learning opportunities available to students.

Based on this perspective, we suggest that learning contexts and learning methods should be mixed, in order to provide a good blend of learning experiences. In particular, compulsory school contexts should include informal learning experiences, such as those described in this article.

Why should informal and formal learning experiences be blended together in school science? We believe that in addition to enriching the repertoire of learning opportunities, such blending can help meet the challenge of 'science for all,' i.e., providing science education tailored to diverse and heterogeneous populations of future citizens (Fensham, 1985). These populations vary both in their interest in learning science and in their abilities to learn science. The integration of informal learning experiences within the formal school curriculum could make an important contribution in dealing with this issue.

While we have good reason to believe that informal learning experiences can enrich school science, we know relatively little about how these experiences can best be integrated into the school curriculum. Future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science.

REFERENCES

BAKSHI, T.S., and LAZAROWITZ, R. (1982) 'A model for interdisciplinary ecology project in secondary school', *Environmental Education and Information 2,* 203-213.

BEIERS, R.J., and McROBBIE, C.J. (1992) 'Learning in interactive science centers', *Research in Science Education 22,* 38-44.

BEIERSDORFER and DAVIS (1994) 'Suggestions for planning a class field trip', *Journal of College Science Teaching 24,* 307-311.

BENNETT, L.M. (1965) 'A study of the comparison of two instructional methods: the experimental-field method and the traditional method, involving science content ecology for 7th grades', *Science Education 49,* 453-468.

BITGOOD, D., PATERSON, G.D. and BENEFIELD, A. (1988) 'Exhibit design and visitor behavior', *Environmental Behavior 20,* 474-491.

BOISVERT, D.L. and SLEZ, B.J. (1995) 'The relationship between exhibit characteristics and learning-associated behaviors in a science museum discovery space', *Science Education, 79,* 503-518.

BORUN, M. (1989) 'Naive notions and the design of science museum exhibits.' *Journal of Museum Education 14/2,* 16-17.

BOUD, D., DUNN, J. and HEGERTY-HAŻEL, E. (1986) *Teaching in Laboratories,* Surrey, England, SHRE/NFER-NELSON.

BRADY, E. (1972) 'The effects of field trips compared to media literacy in teaching. Selected environmental concepts', Ph.D. dissertation, Iowa State University.

CHEN, M. (1983) 'Touched by science. An explanatory study of children's learning from the second seasons', '3-2-1 Contact', in Children's Television Workshop, New York.

CHEN, M. (1994) 'Television and informal science education', in Crane, V.T., Nicholson, T. & Chen, M. (ed.), *Informal science learning: what research says* *about television, science museums and country based projects.* Epharata, Pennsylvania, Science Press.

CLEMENSON, D. (1977) 'Project assessment, a sample analysis', *Assessment in Higher Education 2,* 196-221.

CRANE, V., NICHOLSON, T. and CHEN, M.(1994) 'Informal science learning', in *What the research says about television, science museums and community-based projects,* Epharata, Pennsylvania, Science Press.

DIAMOND, J. (1986) 'The behavior of family groups in science museums,' *Curator 29/2,* 139-54.

DIAMOND, J. (1992) 'New directions for research,' in Nichols, S. (ed.) *Patterns in Practice: Selections from the Journal of Museum Education,* Washington, D.C.: Museum Education Roundtable, pp. 187-190.

DYAMOND, F., GOODRUM, D. and KERR, I. (1990) 'Evaluation of SCITECH exhibit', (Report) MASTEC, College of Advanced Education, Perth, WA, Western Australia.

EYLON, B., HOFSTEIN, A., MAOZ, N. and RISHPON, M. (1985) 'Extra-curricular science courses: filling a gap in school science education', *Research in Science and Technological Education 3,* 81-89.

FALK, J.H. (1983a) 'Field trips: a look at environmental effects of learning', *Journal of Biological Education 17,* 137-142.

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

FALK, J.H., MARTIN, W. and 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.

FALK, J.H. and BALLING, J.D. (1980) 'The school field trip: where you go makes a difference', *Science & Children 17,* 6-8.

FALK, J.H. and BALLING, J.D. (1982) 'The field trip milieu: learning and behavior as a function of contextual events', *Journal of Education Research 76,* 22-28.

FALK, J.H., KORAN, J.J. and DIERKING, L.D. (1986) 'The trips of Science: assessing the learning potential of science museums', *Science Education 70,* 503-508.

FEHER, E. (1990) 'Interactive museum exhibits as tools for learning: explorations with light', *International Journal of Science Education 12,* 35-39.

FEHER, E. and RICE, K. (1988) 'Shadows and outimages: children conceptions of light and vision II', *Science Education 72,* 637-649.

FENSHAM, P.J. (1985) 'Science for all', *Journal of Curriculum Studies 17,* 415-435.

FIDO, S.H. and GAYFORD. G.C. (1982) 'Field work and the biology teacher: a survey of secondary schools in England and Wales', *Journal of Biological Education 29,* 74-75.

FINSON, K.D. and ENOCHS, L. (1987) 'Students attitudes towards science-technology society resulting from a visit to a semi-technology museum', *Journal of Research in Science Teaching 24,* 593-609.

FORTNER, W. and TEAFES, T.G. (1983) 'Baseline studies for marine education: experiences related to marine attitudes and knowledge. *Journal of Environmental Education 11,* 11-19.

FRASER, B. (1979) *Test of Enquiry Skills - TOES,* Melbourne, Australian Council for Educational Research.

GOTTFRIED, J. (1979) *A naturalistic study of children's behavior in a free-choice learning environment.* (Unpublished Ph.D. dissertation, University of California, Berkeley).

HARVEY, H.W. (1951) An experimental study of the effects of field trips upon the development of scientific attitudes in a 9th grade general science class. *Science Education,* 35, 242-248.

HICKMAN, E.W. (1976) 'The status of field trips as a method of science instruction in Oklahoma high schools and factors affecting its use', Ph.D., University of Arkansas, Fayetvile, AR, USA.

HOFSTEIN, A. and KEMPA, R.F. (1985) 'Motivating strategies in science education: attempt at an analysis', *European Journal of Science Education 7,* 221-229.

HOFSTEIN, A. and WALBERG, H.J. (1994) 'Instructional strategies', in Fraser, B., and Walberg, H.J. (eds.), *Improving Science Education,* International Academy of Education, The NSSE Year Book.

JAVLEKAR, R.D. (1989) 'Learning scientific concepts in science centers', in Bitgood, D. (ed.), *The 1984 Visitor Studies 2,* 168-179. Center for Social Design, Jacksonville, AL, USA.

JOHNSTONE, J. and R. LUKER. (1983). The "Erikson" study: an exploratory study of viewing two weeks of the second season of 1-2-3 Contact. New York Children Television Workshop.

KAGAN, D.M., and FASAN, V. (1988) 'Stress and the environment', *College Teaching 36,* 75-80.

KEMPA, R.F. and DIAZ, M.M. (1990a) 'Motivational traits and preferences for different instructional modes in science education', Part I, *International Journal of Science Education 12,* 195-205.

KEMPA, R.F. and DIAZ, M.M. (1990b) 'Motivational traits and preferences for different instructional modes in science education', Part II, *International Journal of Science Education 12,* 195-205.

KERN, E.L. and CARPENTER, J.R. (1986) 'Effect of field activities on student learning', *Journal of Geological Education 34,* 180-183.

KILPATRICK, W.H. (1951) *Philosophy of education,* New York, McMillan.

KORAN, J.J. and BAKER, D.S. (1979) 'Evaluating the effectiveness of field experiences', in Rowe, M. (eds.), *What Research Says to the Science Teacher 1,* 55-67, Washington DC, NSTA.

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

KREPEL, W.J. and DURALL, C.R. (1981) *Field trips: a guideline for planning and conducting educational experiences,* Washington DC, NSTA.

KROPF, M. (1989) 'The family museum experience: a review of the literature,' *Journal of Museum Education 14/2,* 5-8.

KUBOTA, C. and OLSTAD, R. (1991) 'Effects of novelty-reducing preparations on exploratory behavior and cognitive learning in a science museum setting', *Journal of Research in Science Teaching 28,* 225-234.

LAETSCH, W., DIAMOND, J., GOTTFRIED, J. and S. ROSENFELD (1980) 'Children and family groups in science centers'. *Science and Children 15,* 14-17.

LAM-KAN, K.S. (1985) 'Contributions of enrichment activities towards science interest and achievement', EdD dissertation, National University of Singapore.

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 Dynan, M. and Fraser, B. (eds.), *Informal learning of science,* Western Australian Institute of Technology, pp. 1-10.

LUCAS, A.M., McMANUS, P. and THOMAS, G. (1986) 'Investigating learning from informal sources: listening to conversations and observing play in science museum', *European Journal of Science Education 8,* 341-352.

MADDEN, J.C. (1985) 'To realize our museum's full potential', *The Journal of Museum Education 10,* 3-5.

MARTIN, W.W., FALK, J.H. and BALLING, D.C. (1981) 'Environmental effect on learning: the outdoor field trip', *Science Education 65,* 301-311.

MASON, J.L. (1980) 'Bibliography of field trips research', *School Science and Mathematics 80,* 155-156.

McCLAFFERTY, T. and RENNIE, L. (1992) 'Learning and rallying in science education events', The Australian Science Education Research Association (ASERA), Canberra.

McKENZIE, G., UFGARD, R. and LISOWSKI, M. (1986) 'The importance of field trips: a geological example', *Journal of College Science Teaching 6,* 17-20.

McNAMARA, P. (1987) 'Visitor participation in formative exhibit evaluation', *Journal of Museum Education 12/1* , 9-11.

MIRKA, G.D. (1970) 'Factors which influence elementary teachers use of out-of-doors', M.Sc. dissertation, Ohio State University.

OPPENHEIMER, F. (1986) *"Working prototypes" Exhibit Design at the Exploratorium.* San Francisco: The Exploratorium.

ORION, N. (1993) 'A model for the development and implementation of field trips as an integral part of science curricula', *School Science and Mathematics 93,* 325-331.

ORION, N. (1994) 'A short-term and long-term study of a science investigation project in geology, used by non-science high school students', *Research in Science and Technological Education 12,* 203-223.

ORION, N. and HOFSTEIN, A. (1991) 'The measurement of students' attitudes towards scientific field trips', *Science Education 75,* 513-523.

ORION, N. and HOFSTEIN, A. (1994) 'Factors that influence learning during a scientific field trip in a natural environment', *Journal of Research in Science Teaching 31,* 1097-1119.

OSGOOD, C.F., SUCI, G.I. and TENENBAUM, P.H. (1975) *The Measurement of Meaning,* Urbana University Press.

PIAGET, J. (1964) 'Development and learning', *Journal of Research in Science Teaching 2,* 176-186.

REED, G. (1972) 'A comparison of the effectiveness of the planetarium and the classroom, chalkboard and celestial globe in the teaching of space and astronomical concepts', *School Science and Mathematics 72,* 368-374.

RESEARCH COMMUNICATIONS LTD. (1992) 'The impact of using the FUTURE series on junior high school students', Dedham Massachusetts, USA.

RICE, K. and FEHER, F. (1987) 'Pinholes and images: children conceptions of light and vision, 1', *Science Education 71,* 629-639.

ROSENFELD, S. (1979) 'The context of informal learning in zoos', *Roundtable Reports 4,* 3-8.

ROSENFELD, S. (1980) *Informal learning in zoos: naturalistic studies of family groups.* (Unpublished Ph.D. dissertation, University of California, Berkeley).

ROSENFELD, S. (1982) 'Naturalistic study of visitors and interactive mini-zoo', *Curator 25,* 187-212.

ROSENFELD, S., PUNDAK, D. and LURIA, Y. (1995). Learning how to investigate in the natural sciences: training teachers to guide student research. In: Aarnoutse, C. *et al.* (eds.), *6th European Conference for Research on Learning and Instruction (EARLI).* Nijmegen, MesoConsult Press.

ROSENFELD, S. and TERKEL, A. (1982) 'A naturalistic study of visitors at an interactive mini-zoo', *Curator 25/3* 187-212.

RUDMAN, C.L. (1994) 'A review of the use and implementation of science field trips', *School Science and Mathematics 94,* 138-141.

SCREVEN, C.G. (1990) 'Uses of evaluation before, during and after exhibit design', *ILVS review 1,* 101-175.

ST. JOHN, M. (1990) *First-Hand Learning: Teacher Education in Science Museums.* Washington, D.C.: Association of Science-Technology Centers.

ST. JOHN, M. (1992) 'Evaluating visitors' conversations with exhibits, in Nichols, S. (ed.), *Patterns in Practice: Selections from the Journal of Museum Education,* Washington, D.C.: Museum Education Roundtable, pp. 191-195.

ST. JOHN, M. and PERRY, D. (1993) 'A framework for evaluation and research: science, infrastructure and relationships'. In Bicknell, S. & Farmelo, G. (eds.), *Museum visitor studies in the 90s,* London: Science Museum, 59-66.

STARR, K. (1990) 'MER at 20: Science observations on museum education', *Journal of Museum Education 15,* 18-19.

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.

TAMIR, P. and FRIEDLER, Y. (1994) 'Research associated with the Israeli high school biology program', *Studies in Education Evaluation 20,* 321-336.

TAYLOR, S. (1986) *Understanding processes of informal education: A naturalistic study of visitors to a public aquarium.* (Unpublished Ph.D. dissertation, University of California, Berkeley.)

TOBIN, K., CARIE, W. and BETTENCOURT, A. (1988) 'Active teaching for higher cognitive learning in science', *International Journal of Science Education 10,* 17-27.

TYTLER, P. (1992) 'Independent research projects in school science: case studies of autonomous behavior', *International Journal of Science Education 14,* 393-411.

WELLINGTON, J. (1990) 'Formal and informal learning in science: the role of the interactive science centers', *Physics Education 25*, 247-252.

WELLINGTON, J. (1991) 'Newspaper science, school science; friend or enemies?', *International Journal of Science Education 13* (4), 363-372.

WOLF, R. and TYMNITZ, B. (1979) 'Do giraffes ever sit? A study of visitor perceptions at the National Zoological Park.' Washington, D.C.: Smithsonian Institution.

WOOLNOUGH, B.E. (1994) *Effective Science Teaching*. Buckingham: Open University Press.

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

YAAKOBI, D. (1981) 'Some differences in modes of use of an environmental education programme by school teachers and community leaders', *European Journal of Science Education 3,* 69-76.