OUTLINE OF A TECHNOLOGY FOR EFFECTIVE SCIENCE EXHIBITS

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ABSTRACT. A framework is proposed for the systematic application of objective knowledge to the solution of practical problems in mounting didactic exhibits. It brings together aspects of educational technology and observations on the behaviour of visitors in museums, to form a museum technology. This has a common basis with educational technology in the nature of the learning process, but as educational institutions, museums are distinguished by their informality and by the heterogeneity of their learners. Attraction and holding are valuable measures of exhibit effectiveness; a new model is developed to sharpen and extend the applicability of these concepts. The practical value of museum technology is summarized in a series of precepts for the design of effective exhibits. These form two sets; the first is derived from observational studies and concerns architectural factors, the second is based on selected aspects of educational technology.

MOST curators of palaeontological collections tend to be involved to some extent in exhibition work, and therefore the philosophy behind it is an important part of curation. The views set out in this paper have been acquired during the first stages of work on a large, new exhibition scheme in the British Museum (Natural History) (Miles and Tout 1978). This scheme will eventually deal with all aspects of natural history and we believe that our conclusions apply therefore to palaeobiological as well as to other scientific displays.

Museum displays have often been the subject of criticism in specialized publications and the popular press, but whether the opinions expressed have any meaning or value has seldom been considered. Are they purely subjective, or are they at least potentially objective like judgements in scientific research? Can the quality of the criticism be explained, defended, and above all improved? These are the questions considered in this paper, which stems from a conviction that if we can improve the quality of our criticism then we can improve the quality of our exhibits. Displays have often been modernized by changing their style (Swiecimski 1977*a*, *b*, *c*), but there have been few attempts to analyse their purpose, assess their effectiveness, or systematically improve their performance (see also Loomis 1973). At the moment exhibition design is a somewhat haphazard process, but if we can agree on a set of critical standards, and build up an organized body of objective knowledge, then we can begin to make real progress in this field.

Criticism is an intellectual skill which plays a recognizably important role in the humanities and the fine arts, but it has an even more fundamental role in science (Macdonald-Ross and Waller 1975). The argument that criticism is essential to the growth of scientific knowledge has frequently been expressed, particularly by Popper (e.g. 1976, pp. 22, 23):

> . . . the only intellectually important ends are: the formulation of problems, the tentative proposing of theories to solve them; and the critical discussion of the competing theories. The critical discussion assesses the submitted theories in terms of their rational or intellectual value as solutions to the problem under consideration; and as regards their truth, or nearness to truth. Truth is the main regulative principle in the criticism of theories . . .

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A statement about exhibition design such as 'exhibits should be well lighted', regardless of its intrinsic merit, has a logical status which depends very much on the context in which it is made. In the context of criticism, it defines a criterion against which to judge existing exhibits; in that of planning, it has a prescriptive or normative role telling us how to reach accepted goals. Both contexts occur in this paper. In the first part we shall discuss a scientific approach to the problem of improving the effectiveness of museum exhibits, with particular emphasis on the role of criticism. In the last section we shall gather together an initial set of precepts resulting from this approach and thus provide the prescriptive context.

SCIENCE MUSEUMS AND MUSEUM SCIENCE

Museums differ in their purposes. Many, especially those concerned with the arts, traditionally have the aim of collecting and preserving objects of intrinsic merit and of putting at least some of these on public display. Others are concerned with science, and consequently tend to place less emphasis in their exhibits on objects and more on ideas. For this last category there is no logical reason why the scientific method (which has led to a vast increase of knowledge and understanding in many different fields) should play an important part in the advancement of knowledge and then be ignored when it comes to diffusing this knowledge more widely.

This outlook provides a framework within which it is possible to take a fresh look at the process of exhibition design. This framework is characterized by the criticism-based schema of Popper (1972, p. 287), a three-stage iterative process of trial and error:

$$P_1 \longrightarrow TT \longrightarrow EE \longrightarrow P_2$$

where P = problem, TT = tentative theory, EE = '(attempted) error elimination, especially by critical discussion'. Once it is accepted that exhibits may be regarded as trial solutions to suitably defined problems, the four entities linked in these three stages can be identified in the context of exhibition design:

1. *Initial problem.* Problems take many forms in exhibition design. For example, they concern the effectiveness of exhibits in communicating facts and ideas, the visitors' difficulties in finding their way around the exhibits, and the attraction and holding of visitors' attention. Such problems may be difficult to identify and describe, but each must be clearly formulated if a solution is to be proposed and tested.

2. *Tentative theory.* This is the trial solution to a problem. In the practical context of exhibition work the solution normally takes the form of specifications for an exhibit or larger part of an exhibition.

3. *Error elimination.* This involves the criticism of the trial solution by the realization of an exhibit or larger part of an exhibition, and the evaluation of its performance against previously fixed standards. In other words, the theory is put to the test to reveal its limitations.

4. *New problem.* The elimination of errors in a theory leads ideally to a more refined solution. The new solution can then be pitted against a deeper interpretation of the original problem. We must assume that it is always possible to make further progress (i.e. learn how to do the job better) because we have no means of knowing when we have arrived at a perfect solution. This assumption gives purpose and direction to work, though in practice it may never be feasible to test and improve exhibits beyond the point where they function adequately according to the criteria applied to the exhibition as a whole.

The same framework underlies the approach in the broader field of operational research (e.g. Churchman *et al.* 1957; Waddington 1973, pp. 25–30), and the more specific one of educational technology (e.g. Rowntree 1974) in which there are many ideas relevant to the design of museum exhibits.

THE SCIENCE MUSEUM AS AN ENVIRONMENT FOR LEARNING

It seems reasonable to assume that most science exhibits are set up with the aim of communicating ideas, e.g. to tell a story, explain a concept, suggest a new attitude, or reveal the interest of a particular object or phenomenon that might otherwise escape attention. We may also assume that most visitors enter a science museum with the expectation of learning something, though frequently such expectations may be ill-defined. From these two assumptions it follows that science museums are potentially places where people learn (Shettel 1968, 1973; Screven 1969, 1976; Lakota and Kantner 1976). That is, science museums can provide learning environments for the general public. Further, the sort of learning environment provided by a public science museum is unique in its informality and in the freedom afforded to the learner. Thus, visitors can extend their knowledge and understanding in whatever direction they choose; they do not have to conform to any set of values other than their own; and they can come and go as they please, moving about at their own pace and on their own terms. The only thing asked is that visitors behave in a socially acceptable manner.

These points have, *inter alia*, been summarized by Thier and Linn (1976, p. 234):

1. People come to science centres and museums generally by choice.
2. People choose activities suited to their own needs.
3. Individuals can interact with materials that might not otherwise be available.

THE RELEVANCE OF EDUCATIONAL TECHNOLOGY

Discussion above refers to science in connection with museums and the link of technology with education. Since our principal concern in what follows is with museum technology (Oppenheimer 1968, p. 169; Miles and Tout 1978), it is appropriate to distinguish between the ways in which we use the terms 'science' and 'technology'. Both are associated with the idea of research as a purposeful activity by which knowledge is advanced. However, not all research is scientific and not all scientific research follows the same pattern.

The present discussion relates only to that which is conducted according to Popper's schema (see above), and we recognize the following categories:

1. *Applied research.* The main purpose is to find a way of doing some particular thing.
2. *Pure research.* The main purpose is to advance knowledge. Two kinds may be distinguished.
   - 2.1. *Basic research.* The purpose is to advance knowledge in a particular field to make it easier to solve problems in that field.
   - 2.2. *Fundamental research.* There is no apparent prospect of putting the new knowledge to practical use.

Different names are sometimes used for these three types of research, but this is less important than distinguishing the underlying differences in purpose.

Science (in a restricted sense) is the underlying body of objective knowledge built up by applied, basic, or fundamental research. A technology, for our purposes, is a body of scientific knowledge relevant to a particular field of activity. Technology (as an activity) is the application of science to the solution of practical problems. It may use the results of fundamental research, but technological research must be either applied or basic because its purpose is never just the increase of knowledge. There are thus three important aspects of technology:

1. The organized body of objective knowledge which results from scientific research.
2. The extension of this knowledge by scientific research.
3. Practical purposes which underly this further research.

Purpose is so central to technology that it must be defined unambiguously by clearly stated objectives (p. 214).

The technological approach to design in education began with programmed learning, which led to the ideas underlying educational technology, i.e. the learner not the teacher as the focus of attention; giving the learner control over his or her own rate of working; and providing for mixed ability and attainment, e.g. by introducing branching points into the sequence of instructional material. Science museums are different from schools and adult institutes in formal education (Thier and Linn 1976, p. 234) but the learning process is much the same everywhere. Therefore, museum technology and educational technology are distinct but the two have considerable overlap. The biggest differences arise from the extreme heterogeneity of museum visitors and their freedom of action.

The museum, no less than the teacher (e.g. Tammadge and Starr 1977), has to (1) motivate, (2) set the scene in which learning can take place, and (3) present information in such a way that learning becomes enjoyable and rewarding. The affective aspects of the learning process (Krathwohl *et al.* 1964) present more difficulty than the cognitive ones, and perhaps carry slightly more weight in the museum than in formal education, but apart from this the features of educational technology most relevant to the museum exhibition are listed below. Most of these are characteristic of programmed learning, but for continuing changes in emphasis (Shettel 1968, 1973; Screven 1969, 1976; Macdonald-Ross 1969; Davies 1971; Rowntree 1974; Lakota and Kantner 1976).

1. The statement of aims is in the form of specific objectives, i.e. in potentially measureable terms.

2. The content of the course of study (exhibition) is carefully arranged so as to present the underlying ideas in a logical sequence. Not all writers accept that this feature is appropriate to museums (Cameron 1968, p. 37; Shaw 1972, p. 43), but axiomatically this precept must be followed if the museum wishes to provide a proper setting for individualized learning and at the same time present science as an organized body of knowledge.

3. The interaction between the learner and the subject material (exhibits) is carefully controlled by:

(*a*) arranging the material in digestible steps;

(*b*) making provision for various levels of ability, knowledge, and interest, *inter alia* through 'enrichment' material;

(*c*) making provision for participation or active responding, though not necessarily through overt responses;

(*d*) making arrangements for immediate confirmation of responses (i.e. 'feedback' after a correct response).

4. The medium is matched to the subject material and learners at all stages. This subject is largely beyond the scope of this paper and therefore receives only passing mention.

5. The materials are subjected to validation and evaluation.

THE EMERGENCE OF A MUSEUM TECHNOLOGY

Until recently, the role of trial and error and the importance of objective criticism were not widely recognized as relevant to the design of exhibitions. Thus, Parr (1962, pp. 36–37) was able to write:

> beyond the esthetic satisfaction it provides, we have no evidence of what effects good design may have upon our ability to communicate knowledge and create understanding by visual means. In fact, we do not even seem to have rigorous proof that design makes any difference at all to the educational value of an exhibit, however great our personal faith in the designer's art. And we are making no serious attempt to arrive at objective appraisals of performance in the tasks to which we are dedicated.

The turning point came more or less at the same time as the publication of a small-scale study on the criteria habitually employed by specialists developing, producing, and teaching from exhibits (Shettel 1968). Shettel argued that if these criteria (e.g. 'exhibits should be well lighted') were necessary and sufficient for the design of effective exhibits, then experts in the field, upon examining a given exhibit, should agree whether it did or did not meet these criteria. In other words, he was interested in discovering whether existing precepts for effective design provided adequate critical standards for judging exhibits.

A draft list for measuring exhibit effectiveness was produced with fifty-five criteria drawn from the literature. These criteria were sorted into fifteen basic sets (Shettel 1968, table 1) 'including: ability to attract attention; accuracy of information presented; relation of exhibit to surrounding area and other exhibits; design of exhibit including use of colour, light and contrast, etc.; the items contained within the exhibits; and the use of various communication techniques such as sound, motion, demonstration, films, etc.'. Initially these were rated on a six-point scale, but after trial this was replaced by a four-point scale.

We may ignore some of the subtleties in the design of the draft list, e.g. to check the internal reliability of the ratings, and it will be sufficient to consider only the results of its first trial. As Shettel (1973, p. 35) notes, these were not very encouraging. For example, 'One of the items queried: "How would you rate the overall design of the exhibit?" The following results were obtained from six specialists who were rating the same exhibit: One said it was "excellent"; one said it was "very good"; one "high average"; one "low average"; and two "fair". Whatever *overall design* means to the authors of the exhibit literature, it certainly meant different things to the six raters.'

Shettel's results came from a small experiment using draft criteria, and involved a heterogeneous group of experts (designers, production staff, interpreters, etc.). Therefore, we must be cautious in interpreting these results. Also, it would be wrong to dismiss the tacit knowledge of designers just because it is the result of experience rather than book learning, and has not been developed by orthodox experimental methods (Macdonald-Ross and Waller 1975, p. 77). However, applying this knowledge to the criticism of existing designs is one of the ways it becomes public knowledge, and Shettel's work showed that in one trial at least, tacit knowledge did not provide criteria for the consistent judgement of science exhibits. This does not mean that common sense has no part to play (e.g. see Hjorth 1971). But it does strongly suggest that more exacting, more objective criteria are needed before better exhibits can be developed in a systematic way. Shettel's (1968, p. 150) own major conclusion has considerable interest for the last section of this paper:

> One observation stands out very clearly as a result of this small-scale study, and that is the need for more clearly stated objectives for exhibits.
>
> . . . The question which should be asked is, 'Specifically *what* do you want *whom* to do, know, or feel after seeing the exhibit that they could not do, know or feel before seeing the exhibit?' Answering such a question in adequate detail would cut through much of the ambiguity, and even mystique, that surrounds the exhibit field.

Shettel's work was followed by two events of major importance. These were the realization that some aspects of educational technology might usefully be applied to exhibit design (Screven 1969; Shettel 1973; Lakota and Kantner 1976; Thier and Linn 1976), and the rediscovery of observational work on museum visitors (Melton 1935; Lakota 1975; Lakota and Kantner 1976). The linkage of educational technology and observational work led in turn to the emergence and development of museum technology.

Technology facilitates the making of predictions (e.g. about the interaction between visitors and exhibits), with the practical aim of making better decisions in particular circumstances. In this context, Lakota, Shettel, Screven, and other American workers apparently believe that man's actions, though they stem from a small set of basic drives, are fundamentally responses to external stimuli. This leads to the questionable conclusion that the visitor's behaviour can be determined completely by controlling the conditions. However, this question need not concern us because the matter is surely of theoretical rather than practical interest. The body of objective knowledge making up museum technology can *not* be regarded as a set of laws which permits the prediction of the future state of a fully deterministic system. People visit museums for many different reasons (Morris 1962; Alt 1977, pp. 254–255) and there is no means of telling what knowledge or interest any given visitor will bring to bear on the exhibits, how he will interact with other people in the museum, or how he will be influenced by his expectations of the visit. In short, the number of stimuli to which visitors might respond and the degree to which the response can vary from one individual to another are so great, that it would be a hopeless task to predict the behaviour of a particular visitor. The only practicable possibility is of making predictions concerning populations, not individuals. This has been recognized in the training field, where the original criterion of 100% of the learners attaining 100% of the learning objectives has largely been replaced by the more realistic 90/90 criterion or something similar.

In museums, where the visitors form an extremely heterogeneous population, sights must be set much lower, but this does not mean that museums should abandon educational exhibits. Treating a museum exhibition as a medium for education gives purpose to the process of design in a way that, as far as we are aware, no alternative view of museums does. Persons producing exhibits should, in this view, take it for granted that they are working in an educational medium, in the same way that most teachers know that their job is educating 'regardless of the number of failures among their pupils' (Alt 1977, p. 248). Of course, it is a legitimate part of the designer's art to capture the imagination of the casual visitor and turn him or her into a serious learner. This is the same as the teacher motivating the pupils, but it is not the same as assuming that people are infinitely mouldable, and whatever the intention of the authors we cite when discussing the evaluation and improvement of exhibits, we reject this assumption.

APPLYING THE TECHNOLOGY

The extent to which the precepts of educational technology are applicable in the informal learning environment of a science museum, and that to which the results of limited observational studies in disparate institutions can be applied to science museums in general, can only be established by a process of trial and error. At the very least, applying precepts from these two sources provides a starting-point for the development of more effective exhibits, as in de Morgan's paradox—'wrong hypotheses, rightly worked from, have produced more useful results than unguided observation' (Løvtrup 1974, p. 491). The outcome from applying these precepts is a set of specifications for an exhibit or larger part of an exhibition, which we have identified with the 'tentative theory' of Popper's schema (p. 210), and which is then put to the test by realization, followed by measurement of performance and comparison with previously fixed standards or criteria. Here we can again draw on educational technology and observational studies, this time to provide objective criteria of greater use than those examined by Shettel (1968).

The process of testing is complicated by the very large number of variables involved in the design of even a single exhibit. But more importantly, testing is not possible until another problem has been solved, that of defining effectiveness and specifying the effectiveness criterion in precise terms. Exhibit effectiveness may be defined as 'the measurable transmission of information about scientific principles from the exhibits to the visitors' (Eason and Linn 1976, p. 46); but what information, and what kind of visitors?

In making predictions about interactions between visitors and exhibits it is not possible to consider individuals even if we limit ourselves to the serious learner (p. 214). Our predictions must concern populations of visitors. And the confidence with which we can make these predictions depends on two things; (1) the risk which we are prepared to accept of being wrong, which we can control; and (2) the variation within a particular population, which we cannot control, though we can subdivide the total population into less heterogeneous parts. Such a subdivision was tacitly made above, when the casual visitor was distinguished from the motivated learner.

It is helpful to consider the interaction between visitors and exhibits in the form of a matrix, by supposing a population of m visitors and an exhibition of n exhibits, the individual visitors and exhibits each being identified by a particular value of a subscript, i and j respectively. Let the time spent by visitor i on exhibit j be t_{ij}, which in many instances is likely to be zero (Melton 1935), and let the number of 'non-zero interactions' with exhibit j, i.e. the number of visitors who spend more than a (specified) minimum time at it, be p_j (text-fig. 1). The raw data of the matrix, i.e. the t_{ij}, are of less interest than various totals:

T_j—total time spent by all visitors at exhibit j

T_i—total time spent by visitor i at all exhibits

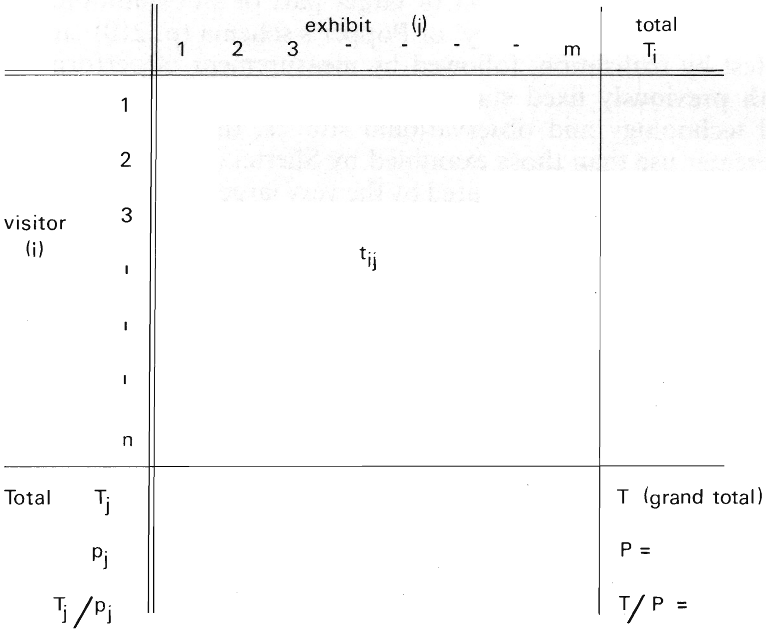
T—total time spent by all visitors at all exhibits

P—total number of non-zero interactions with all exhibits.

However, it is statistics derived from these totals which are the most useful measures of exhibit effectiveness. Attraction and holding are agreed to be the best general measures in this context (Melton 1935; Shettel 1968, 1973; Screven 1976; Lakota 1975; Lakota and Kantner 1976).

Attraction, or frequency of stops, is defined as 'The number of people in the target population who enter a predefined area and the number of these who stop (look) at any part of the exhibit for five seconds or more'.

Holding, or duration of viewing, is defined as 'The total minutes and seconds each visitor remains at the exhibit' (Screven 1976, p. 281). However, it is obvious that holding is correlated with the characteristics of an exhibit, e.g. length of text, and therefore it should be linked to some index of 'required' viewing time. One such index is the 'holding power ratio', i.e. the actual viewing time over the required minimum viewing time. Thus a score of less than one would mean that visitors were spending less time than is necessary to receive the exhibit's message.



TEXT-FIG. 1. Matrix for visitor/exhibit interaction. Symbols are explained in the text.

The model under discussion generates four statistics of this kind:

p_j/n—attraction of exhibit j

P/mn attraction of whole exhibition

T_j/p_j holding power of exhibit j

T/P holding power of whole exhibition.

This both broadens and delineates more precisely the concepts of attraction and holding. It also defines more precisely the two sub-populations of visitors already referred to, the casual (all t_{ij} below a specified limit) and the educationally motivated (all t_{ij} at or above the limit).

The model can be developed in various ways. 'Museum fatigue' can be measured by the fall in drawing power as j increases, its onset being depicted by plotting against j the number of zeros in the first j columns of the table. The boundary value of t_{ij} can be made different for different exhibits, perhaps being set at the expected upper confidence level for the time taken to read the script in the exhibit, which provides one definition of a target population of visitors. Different boundary values of t_{ij} can be used to define casual and educationally motivated visitors, and thus a third, intermediate, population. Differences in the p_j can be used to identify exhibits as worthy of further study because of high or low holding time (a high holding time may signify a particularly interesting exhibit or a particularly unintelligible one), and likewise particular values of t_{ij} can be used to identify potential subjects for interview in a deeper study of exhibit effectiveness. The scope of the model can be extended by replacing t_{ij} with the general variable x_{ij} representing any measure of particular interest in the study of the exhibit effectiveness (including t_{ij} itself), and we can subject x_{ij} to the analysis of variance to provide the basis for predictions of effectiveness.

Criticism and the consequent attempt to eliminate errors together constitute the process which has come to be known since the early days of programmed learning as evaluation. In terms of when, rather than how it is carried out, a distinction may be drawn between formative and summative evaluation (Scriven 1967; Screven 1976). Formative evaluation is carried out during the development of an exhibition and the results are used to improve the effectiveness of the final product. This evaluation can be carried out on all aspects of an exhibition, including the materials used in its construction, its ability to attract visitors and hold their attention and its communications effectiveness. It is usual to use cheap, easily modified mock-up versions of the exhibits for this work. Eason and Linn (1976, p. 49) give a list of the questions answered by one specific programme of formative evaluation:

1. Do the exhibits work as planned?
2. Are the directions at an appropriate reading level?
3. Can visitors follow the directions provided?
4. Are diagrams clear to visitors?
5. How long do visitors generally spend at each exhibit?
6. What part of the visitor population is interested in optics?

Summative evaluation is carried out after an exhibition has been developed and installed, and aims to discover how well the original planning goals have been achieved. It forms the basis of further action if the exhibition is to be revised, partly replaced, left to stand as it is, or scrapped completely. Formative and summative evaluation are not, of course, mutually exclusive, and there is no reason why formative evaluation should not take place during modification of a completed exhibition, in the light of the summative results.

In both formative and summative evaluation it is necessary for the test criteria to be appropriate, effective, and practical (Davies 1971, p. 212). Failure in one or more of these respects may explain some of the disappointing results obtained so far in measuring the effectiveness of science exhibits (Alt 1977). Test criteria based on detailed factual knowledge may be inappropriate if Thier and Linn (1976, p. 234) are correct in their assumption that visitors are not attracted to science museums to learn facts but rather to discover new and interesting phenomena. And the devising and administration of pre-tests and post-tests to measure changes in knowledge, beliefs, and attitudes, while appropriate in formal education, are not necessarily so in the convivial setting of a public museum (Linn 1976). Factors such as these are probably more important than the problem identified by Shettel (1968, p. 138), of 'designing appropriate measuring instruments that are sensitive to changes'.

Observational work offers a more direct approach to the evaluation of exhibit effectiveness than pre- and post-test questions. The basic premiss is that unless certain readily observed 'conditions of learning' are fulfilled, an exhibit or exhibition cannot possibly be effective. Attraction and holding do not measure the power of an exhibit to increase the visitor's knowledge or change his attitude and beliefs. It is possible for an exhibit to perform well in both respects and still communicate nothing. However, we can be more certain that an exhibit which fails to attract and hold attention will not communicate, regardless of its potential effectiveness in transmitting information. This is knowledge worth having because it forms a firm basis for practical action.

THE DESIGN OF EFFECTIVE EXHIBITS

In this last section we present a set of precepts for the design of effective exhibits, based on the work of Lakota (1975; Lakota and Kantner 1976). As already explained, these define conditions for learning for the visitor whose goal is museum learning. However, we believe that they permit a positive, directional approach to the work of mounting science exhibits, to the benefit of all visitors. The precepts form two overlapping sets. The first is derived from observational studies and concerns exhibit architecture—which Lakota and Kantner believe to have an overwhelming influence on visitor behaviour. The second set is based on the aspects of educational technology already mentioned.

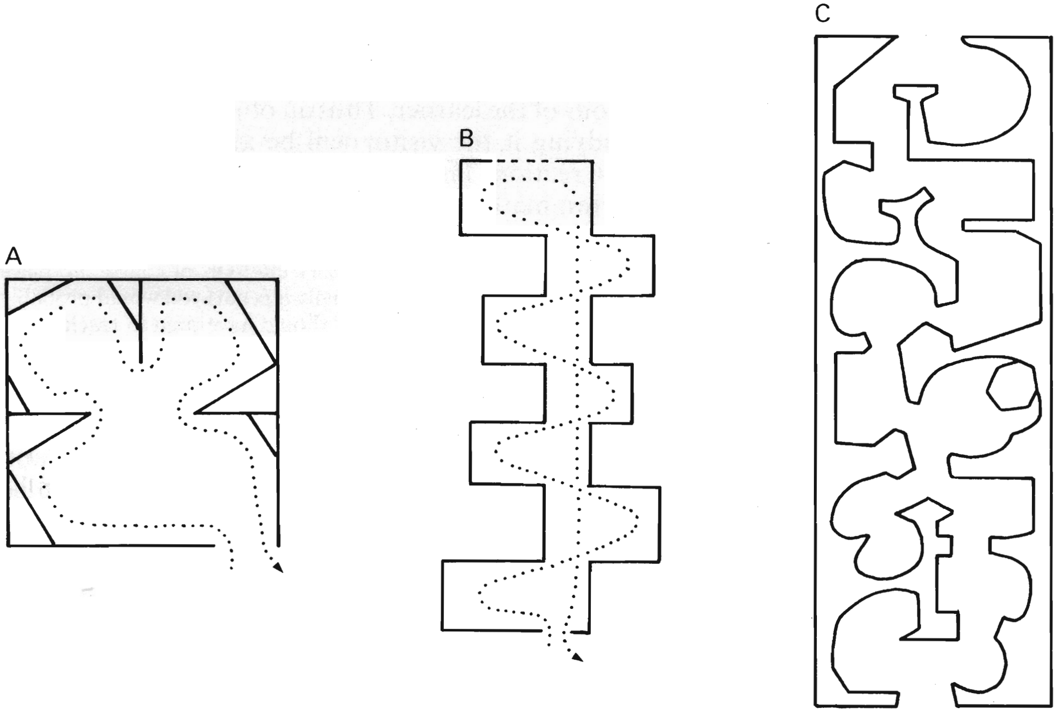
Architectural and organizational factors

1. *The exhibition space should be partitioned into smaller areas with chambers or alcoves large enough for groups of about ten to observe some aspect of the exhibition*

Melton (1935) found that visitors spent most of their time near the entrance of an exhibition and less and less as they approached the exit. The exhibits receiving most attention were those in a direct line between the point where the exit becomes visible and the exit. Even so, speed of movement increased rapidly as the exit was approached. This exit gradient effect can be lessened by constructing exhibitions in a cul-de-sac form with a single entrance and exit (text-fig. 2A). In the case of large rectangular galleries, this means that the entire area must be partitioned into a series of culs-de-sac with a comb-like arrangement (text-fig. 2B). The 'comb' may be regular, or topologically distorted to reduce the exit gradient effect still further (text-fig. 2C). Both types allow for a separate entrance and exit. The culs-de-sac may then be further subdivided into chambers or alcoves off the main traffic paths. This is believed to increase holding power by dividing the content into well-defined steps, isolating the visitor from the distractions of crowd noise and adjacent exhibits, and allowing small groups to interact socially. Large open galleries present such a daunting prospect and seem to require such a large commitment, that many visitors do not progress further than the entrance.

2. *The organizational structure of the exhibition should be clear to the visitors*

Exhibitions with a clear organizational structure appear to have greater holding power than those which have not. This idea presents few problems in the design of small cul-de-sac exhibitions, where visitors can see the over-all arrangement of the exhibits at a glance. The main problem with large galleries is that the over-all organization may not be obvious to visitors. Therefore, in order to guide them an orientation



TEXT-FIG. 2. Subdivision of exhibit space, after Lakota and Kantner 1976. Possible exit shown by broken line in B; main routes shown by dotted line in A and B.

area should be provided at the entrance. This should communicate the organizational plan of the exhibition, and be linked to headings in the individual display areas which clearly state the concepts that are covered. The term 'organizational plan' is intended to cover more than the provision of a map of the gallery, where this is necessary. The aim should be to tell visitors what the exhibition is about, what it has to do with them, how it is organized conceptually, and what they can expect to learn from it. Ideally, all four should then be related to a map of the arrangement of the displays. With a large or complex exhibition, it seems clear that this information should be repeated at given points in the gallery, particularly where visitors might be faced with a choice of routes and therefore a decision about where to go next.

3. *Island display units should be avoided or sited off the main routes through the gallery*

The ability of a gallery to handle large numbers of visitors seems to depend primarily on the width of its major path. Exhibitions with free-standing island displays apparently possess significantly less holding power than those without such displays. It would appear that islands tend to be situated in the middle of the major path through the exhibition and thus reduce path width and increase crowd pressure. Anyone standing around such a display would be essentially blocking crowd flow at its most congested point.

Educational technology factors

1. *Exhibits should have explicitly stated objectives which specify exactly what visitor effects are intended*

Objectives here refer to the behaviour of the learner. Thus an objective for an evolution exhibit might be that after studying it the visitor will be able *to cite* three of Darwin's arguments against Special Creation. The case for objectives has been stated by Rowntree (1974, p. 35) in an epigrammatic form that applies equally well to both education and exhibition planning:

If you don't know where you're going, you're liable to land up some place else! Or, of course, no place at all. But even if the some place else were useful and interesting (and usually it is not) you would probably find yourself with no time or resources left to get to the place you really should have tried to reach.

The practical value of objectives to those working in museums is that they encourage clear thought about the content, organization, and style of exhibits; facilitate communication between those working on the exhibits; and provide an honest foundation for evaluation. Lakota and Kantner (1976, p. 98), however, go much further, and suggest that objectives might be presented to visitors so that they know what can be learned from an exhibit. It is hypothesized that this will give direction to learning and aid visitors in organizing exhibit content. Highly specific objectives will concentrate attention on particular details of an exhibition and decrease incidental learning, while high-level objectives will increase, motivate, and promote incidental learning. An example (after Lakota and Kantner) of a caption with highly specific objectives for a palaeontological exhibit might be:

Look closely at the fossils in this exhibit. By finding their scientific names, and reading their labels, you will be able to:

* Name each fossil when shown its picture;
* Recognize the picture of each fossil when shown the name;
* Identify the order in which the fossils appeared from the oldest to the most recent.

Try it. Test yourself at the end of the exhibit, and see how well you did.

2. *Careful thought should be given to the order in which information is to be learned and this order should be carried through to the design of the exhibits*

Many exhibitions set out to tell a story, and most stories are not disorganized collections of facts (Shettel 1973, p. 40). Wittlin (1971, p. 149) makes the general point that 'Our understanding and appreciation of information grows when details are presented in a clear sequence and in a general context. A message with a beginning and an end has appeal to us.' However, this begs the question of how the information should be sequenced for any given exhibition, although we might assume that the traditional rules of sequence remain useful. These are: proceed from the known to the unknown; from the simple to the complex; from the concrete to the abstract; from observation to reasoning; and from a whole view to a more detailed view of the whole (Davies 1971, p. 41). Other strategies include beginning to end (e.g. in a historical or developmental context), deductive (from reasoning to observation), and geographical. Clearly the published rules sometimes contradict one another, and therefore have to be applied with discretion according to the nature of the exhibition. To this end we have adopted the notion of a concept or learning hierarchy (Gagné 1970) in organizing new exhibitions in the Natural History Museum (Miles and Tout 1978). This hierarchy is based on the theory that in order to understand C, the learner must first understand B. C is usually a concept, and B, its basis, two or more lower-order concepts. It is possible to draw on most of the familiar rules of sequence in constructing a hierarchy, but without having to follow them uncritically.

3. *The material should be arranged in steps of appropriate size*

This point has already been discussed in the context of dividing up the exhibition space into alcoves or chambers. But there is more to be said on the subject from other points of view, and these imply a further subdivision of the material within the alcoves. Firstly there is the fact noted by many authors (Melton 1935; Shettel 1973; Thier and Linn 1976; Linn 1976) that the typical visitor spends less than one minute on any one item in an exhibition. Wittlin (1971, p. 149) suggests that we 'like to use the human capacity to exercise our judgement in keeping with the brief measure of time we spend standing in front of a display'. Secondly, for physiological and perceptual reasons (reviewed by Wittlin 1971), the visitor needs to focus his eyes on single objects that interest him; he needs vacant spaces between these objects; and both his eyes and brain need to rest. Thirdly, from a psychological point of view there is a limit to the amount of information that can be communicated at any one time. Exhibits should provide the visitor with an opportunity to rest his mind; this 'is particularly true of the amount of text on a particular label, which can be easily controlled by dividing up the material into smaller pieces' (Shettel 1973, p. 40). A further method of reducing the length of text is mentioned below (p. 222).

4. *Provision should be made for various levels of ability, knowledge, and interest*

Defining the target audience, for the practical purposes of design, is an exceptionally difficult task in a public museum. One advantage of the learning hierarchy is that it includes all the steps in the story of the exhibition, beginning with the most basic. These basic concepts are those which are assumed to be familiar to visitors when they arrive. The learning hierarchy thus allows for an exhibition which leads even the most uninformed visitors from the familiar through the less familiar to some totally unfamiliar concepts. Nevertheless, it is also important to provide sufficient information for the quicker, better-informed visitors, and the exhibition must be organized so that they do not have to work laboriously from one end to the other, with no freedom to 'skip' familiar material.

Wittlin (1971) has stressed the dangers of trying to combine displays which deliver an interesting and stimulating message to the general visitor (an 'interpretive' exhibit) with a 'scholar's library of specimens' (an 'underinterpretive' exhibit). She contends that such compromise exhibits remain underinterpretive and may even become misinterpretive, with the visitor's attention focused on the design rather than on the subject-matter. One answer to this problem is to provide an interpretive exhibit leading to another of limited interpretation. The general visitor, primed by guidance received in the first, can move on to the second if he or she so wishes. Such exhibits of limited interpretation are equivalent to the enrichment booklets of some modern school courses, and can be regarded as serving the same function, i.e. satisfying the needs of the quicker, more highly motivated learner.

5. *Provision should be made for visitors to engage in active response*

The hypothesis behind this precept is that 'active participation heightens the acquisition and retention of information' (Shettel 1973, p. 40). Several lines of evidence support the case for active rather than purely passive learning (Thier and Linn 1976). However, there is a reason why active participation is particularly appropriate in a science museum. Science is a creative, exploratory activity, and therefore science museums should be places where visitors can ask questions and answer them by their own observations and experiments (Oppenheimer 1968, p. 174).

We must not forget that visitors do in any event respond to exhibits, and that the aim in developing interactive exhibits is to improve the *quality* of that response, and thus the learning that results from it (Lakota and Kantner 1976, p. 122). However, responses do not need to be overt, and in many instances covert responses may be equally effective in stimulating learning, providing they are consistent with the objectives of the exhibition. Overt responses are perhaps most closely identified with mechanical, electronic, or electromechanical devices, but it is with these that the greatest danger of irrelevant activity arises. 'Flipping a switch, pushing a button and turning a crank are, in many instances, examples of participation for participation's sake, and have no useful function in achieving the objectives of the exhibit' (Shettel 1973, p. 40). Further, such devices tend to present severe maintenance problems. Nevertheless, participatory exhibits have been described that are not overtly complex in design. Wittlin (1971), for example, has described a very simple participatory exhibit on human teeth, in which the visitor provides all the elements of movement and response.

Labels which ask questions elicit a special class of covert responses. To be effective, questions should relate to the important features of the exhibition, particularly to specific objectives, and should focus and maintain attention on the objects on display. Question-asking labels have the additional advantage of brevity, and it is claimed that a single question can often communicate more to a visitor than an extensive text panel. With questions as with objectives, the highly specific ones will concentrate attention and reduce incidental learning, while the general ones will stimulate a wider view and increase incidental learning. Lakota and Kantner (1976, pp. 108–110) recommend that highly specific questions be used liberally to maintain visitor attention, and contend that they are best placed before that part of the exhibition containing the related material. On the other hand, general questions, which promote incidental learning and are better for the casual visitor, should be placed after the material. At all events, the best results are obtained when the questions are placed in the closest possible proximity to the exhibit area they refer to.

6. *Feedback should be provided after a correct response*

In designing for a response, the question that designers have asked themselves is: how will visitors know when they have got it right? The notion of feedback in relation to museum learning was originally developed (Screven 1969, p. 9; Shettel 1973, p. 40) on the basis of laboratory experiments on reinforcement. However, being told that your answer is correct is now thought to be less important in learning than was previously believed. Lakota and Kantner (1976, pp. 108–110) have summarized the present state of knowledge as follows: (1) unless feedback conveys new information it has no positive effect on retention; (2) right/wrong feedback is preferable to feedback which corrects a mistake by identifying the correct answer; and (3) it is better to give no feedback at all than to risk giving it before the response has been made.

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DISCUSSION

J. Cooper. How can a museum with limited budgets use Screven's approach of error elimination from finished displays, bearing in mind the cost?

R. S. Miles. Time rather than money may be the limiting factor in developing a sizeable project by formative evaluation. This need not be expensive and Screven suggests that it is particularly appropriate for accountable public institutions.

B. A. Seddon. I find it hard to adopt and accept the guide-lines offered by Dr. Miles, and I prefer to regard his recommendations as merely one of several alternative approaches. It suggests a movement towards propaganda, or coercive route or circuit; it has a declared objective (which is therefore strictly limited) instead of a multi-purpose role, and it restricts the freedom of the visitor to explore and discover (because it is so carefully 'structured').

R. S. Miles. Along with most writers I believe that museums are unique in their informality and in the freedom given to the learner. There is a conspicuous absence of coercive force. A successful attack on the concept of exhibition as an educational medium must first show that this idea works to the disadvantage of the casual visitor, and secondly provide an alternative view which gives equal purpose and direction to the activity of mounting exhibits. I do not know of any well-articulated alternative approach suitable for a science museum. Even so, I agree that didactic exhibits can take many forms.