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ABSTRACT

This study evaluated an experimental program in informal learning, "Light and Illusion," developed by the Vancouver School Board in cooperation with the Arts and Sciences Centre of Vancouver. A mail questionnaire was developed based upon a review of the literature on informal learning. The questionnaire was distributed to the Vancouver School Board teachers who visited the workshop with their students. The study was conducted over a three month period; 94 of the 150 questionnaires sent out were returned (69% return).

The questionnaire sought to determine which teachers (grade level and subject area) used the workshop, how teachers used the workshop, what teachers liked and disliked about the workshop, and what suggestions they had for future workshops. The results were reported as percentage responses to the questionnaire items. In addition, a series of observations and recommendations were made. In particular, the study showed that 90% of the attending teachers were highly satisfied with the workshop as a learning experience for their students. They commented favorably on the quality of the exhibits, freedom of choice, and the noticeable increase in student interest in science.

Elementary teachers rated the workshop more highly than did secondary teachers, although both indicated they benefited by seeing their students work in a novel environment. Teachers thought that further informal learning workshops should be offered to students through the cooperation of the Vancouver School Board and the Arts and Sciences Centre.

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INTRODUCTION

This study is an evaluation of an experimental workshop program, "Light and Illusion," developed by the Vancouver School Board in cooperation with the Arts and Sciences Centre of Vancouver. The workshop program presented multisensory, hands-on exhibits in a school setting for grades 5, 8, and 11 during the year 1980/81. The Light and Illusion exhibits were on loan from the Arts and Sciences Centre of Vancouver.[1] The evaluation was conducted by survey questionnaires (see Appendix) presented to, and completed by teachers of classes visiting Light and Illusion.

The venture, although similar to programs offered by other centres,[2] was unique in Vancouver, and represents a major collaboration of the Arts and Sciences Centre with the Vancouver School Board, and so is one worthy of study. The evaluation of this venture in terms of its effectiveness and value as viewed by teachers, was conceived and planned to provide data on the experimental program, to gain insight into learning in informal learning environments, and to assist in the development of similar projects in the future.

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[1]The exhibits originally were on display at the Arts and Sciences Centre "extended i" Preview Exhibition at the Vancouver Museum, from February to May, 1980. The objective of the exhibition was to provide an interdisciplinary, multisensory and participatory experience for the public in a museum setting.

[2]E.g., The Exploratorium (San Francisco), Ontario Science Centre (Toronto).

The study addresses four major areas and each will be considered in detail: 1. a review of the literature on informal learning; 2. the origin, setting, and operation of the workshop; 3. the workshop in action, its value and its effectiveness as perceived by teachers; 4. a presentation of personal observations arising from the study.

CHAPTER I

A REVIEW OF THE LITERATURE ON INFORMAL LEARNING

As a basis for evaluating the program, Light and Illusion was defined (and conceptualized) as an informal learning environment in contrast to the school which is viewed as a formal learning environment. The phrase 'informal learning environment' is used in the literature to define the type of learning which might occur in a museum type of environment. Informal learning is characterized by free choice, lack of prerequisites and credentials, heterogeneity of learner groups in background and interests, and importance of social interaction as part of the visit (Laetsch, 1980). While it is acknowledged that schools may also provide informal learning experiences the distinction between formal and informal learning is seen as a fundamental one and significant in terms of both the goals and outcomes. In addition, research findings in the psychology of learning will be examined to make evident some variables which affect the outcomes of informal experiences.

The role of traditional museums has been described as the collection and preservation of the artifacts of culture. For nearly two centuries museums have collected and displayed objects from the past, transmitted the cultural heritage and engaged in research to further knowledge. They have frequently carried on these functions without regard for the visiting public and with little or no attention paid to educational programming (Danilov, 1976).

In recent years museums and a new form of public institution, the science centre, have responded to an increasing public demand for educational programming to supplement that offered in the traditional school setting (Danilov, 1976; Eason, 1976). Science centres, in particular, emphasize education over curation and frequently cooperate with local school systems to develop informal learning experiences for children. Science and technology centres may offer personalized exhibits for the teaching of important scientific concepts and thinking skills (Thier & Linn, 1976). In this context active participation is defined as "the ability to interact physically with objects and to manipulate variables" (Laetsch, 1980).

Science centres are among the most rapidly developing institutions in contemporary society, and the number of visitors to these centres is greater than to any other single type of museum (Kimche, 1978). Through exhibits, publications, and educational programs, museums of science and technology are frequently used by teachers to supplement science education (Beardsley, 1975). Alexander (1980) states that a 1972 study of North American museums identified 24 participatory (informal learning) programs for young people, predominantly for fourth through sixth grades. The programs included "hands-on" activities, informal discussions, and "touch-it rooms." However, despite the expanding educational role of museums and science centres,[1] few studies of the educational effectiveness of museum exhibits and programs have been conducted. Indeed, some potentially meaningful variables have not yet been considered. The majority

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[1]So as to avoid constant repetition of museums and science centres, this paper will define museums to include both institutions; this is consistent with terminology of the ASTC which members include both "traditional museums" and "science centres."

of existing studies are concerned with demographic surveys and visitor responses rather than educational evaluations (Kimche, 1978).

Borun (1977) states that a majority of past studies of museum based learning indicate that "little information transfer between an exhibit and a visitor occurs during casual visits." However, Borun goes on to state that the analysis of studies shows that in some cases the lack of measurable learning may be due to the use of inappropriate test instruments. For example, Borun states that pencil and paper tests cannot detect performance based outcomes such as the ability to manipulate learning materials to solve problems. In contrast, Borun, using mechanical testing devices, found that the average casual visitor to a science centre knew over half of the tested information content of the exhibits. Linn (1976) has also shown evaluation of currently available exhibits can increase understanding of the informal learning environment. Linn's and other studies indicated that participatory exhibits produce more positive behavioral outcomes than do static non-participatory exhibits. For example, visitors comment more favourably about participatory exhibits than about non-participatory exhibits. Screven (1976) considers that public displays of art, science, or artifacts are three dimensional teacher/learning situations that may affect the knowledge, values, attitudes, or interests of the people who use them. Wholer (1976) thinks that the museum visitor desires participation in an active, personalized learning process, while Shettel (1973) states that active participation has been shown to heighten the acquisition and retention of information. Screven (1976) has demonstrated that visitor learning was improved when interactive devices were added to static exhibits. Linn (1976) hypothesizes about these learning gains by reference to her study of the Science

Curriculum Improvement Study (SCIS). Linn's study revealed that experiential science programs are better than traditional book-oriented programs in fostering scientific reasoning and logical thinking.

In addition, the value of experiential activites has been demonstrated by Piaget (Kaufman, 1971), whose theories on how children learn form a basis for a variety of recent science education programs. Linn (1976) states that the work of Piaget and Inhelder implies that a program emphasizing concrete experiences are essential to a child's understanding of science. DuTerroil (1975) has stated that activity centre behavior is in keeping with Piaget's beliefs that ". . . children's abilities to deal with broad concepts of space, time, matter, and causality depends on learning that develops slowly from the children's direct sensory experiences." Thier and Linn (1976) state that research is also required to determine what happens when students are allowed to choose their own activities in a free choice setting. They consider that activity designers need to know what sort of information should be presented along with the activities, and what learning is likely to take place in a free choice environment. Indeed, Shulman (1968) states that controversy exists in the literature about the question of how much and what kind of guidance ought to be provided to students in a learning situation.

Gennaro (1981) has reviewed studies which suggest that carefully designed curricular materials and "advance organizers" can be effective instructional strategies for learning new information.

Studies reviewed by Barnes and Clawson (1976) which reported results for students of differing abilities indicated that no trends were identified that would suggest such forms of guidance as "advance organizers" have a differential effect on learning for students of low, average, and high ability. Thier and Linn (1976) found that in chemical exhibits free choice was not enough and that without instruction students were unable to explain their interests any more clearly than, for example, "I want to work with chemicals." A study by Van Rennes (1978) has shown that students learn more about an exhibit when they are provided with a program to direct their inquiry. Shulman (1968) has shown that controversy indeed exists in the literature about the question of how much and what kind of guidance ought to be provided to students in a learning situation.

Falk (1978) also found that subjects in an unfamiliar environment failed to benefit directly from a structured educational activity. Despite their stated preference for a structured introduction to new learning experiences, Thier and Linn (1976) have reported that personalized interactive experiences can have educative value because learners can choose to work on something that interests them. They also state that free choice allows children to work at their own intellectual level and so progress in scientific reasoning.

The School in the Exploratorium Program (SITE)[1] described by Newsom (1978) is an example of a free choice introduction to a new learning experience. The SITE program of science enrichment was organized so that the first of five workshop sessions at the science centre was a field trip during which children were free to explore the exhibit area on their own. Newsom reports that the SITE program is highly regarded by both visiting classes and their teachers.

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[1]SITE is a workshop program for elementary school classes visiting The Exploratorium Science Centre in San Francisco.

Linn (1976) has also stated that learning of science content is only a part of the outcomes of a visit to a science centre. He suggests museums should be more concerned with stimulating visitors' interest than in insuring that factual learning has occurred during a visit. Another researcher, Screven (1976), distinguishes between the 'teacher-learning' aspects of an exhibit (what an exhibit potentially can teach or communicate) and its 'motivational aspects' (which determines the amount of attention an exhibit receives). He goes on to state that effective exhibits should integrate both learning and motivational aspects.

Laetsch (1980) suggests that more research into the free choice learning environment is required to identify factors which elicit curiosity and motivate people to attend activities long enough for learning goals to be realized. Research studies (Berlyne, 1966; Travers, 1972; Kaplan, 1978) have shown that novelty and complexity are variables which will attract and hold a learner's attention to information being presented, while Gottfried (1979) states that novel learning environments promotes exploratory behavior, which is prerequisite to higher forms of learning behavior.

However, studies have also shown that reactions to a particular learning experience vary from individual to individual (Gottfried, 1979; Bruner, 1966). A survey by Peterson (1976) of museum visits by school groups indicated that some children "love exhibits" while others found the same exhibits "boring." Linn (1976) has suggested a number of variables to account for the different reactions, such as length of exposure to an exhibit, the visitor's age, previous science courses, or other variables yet to be identified.

It has also been demonstrated (Gottfried, 1979) that interaction between visitor and exhibit and interaction between visitors and other people in the museum environment contributes to the learning which occurs. Cone (1978) reports that children in a family unit visiting a museum learn about exhibits largely through explanations offered by parents. Gottfried (1979) reports that social factors such as group size and peer teaching influenced exploratory behavior and learning. Among art museum goers who answered the National Research Centre's New York State survey, 77% cited the importance of family friends or teachers in creating cultural interests (Newsom, 1978).

Newsom (1978) also states that the "most important audience of all for the museum educator" may well be the classroom teacher. A teacher has charge of a school class several hours a day, and a good teacher often has a lifelong effect on his students. However, various studies have shown that teachers are sometimes uncomfortable on a field trip to a museum with students because they lack the skills to adequately prepare and guide students through a field trip experience (Alexander, 1980; Newsom, 1978). Thus, a variety of museums and related institutions have undertaken inservice programs to better equip teachers to deal with the museum setting (Newsom, 1978). Teachers reported that training sessions helped them to "know what to expect from the museum and to get excited about it" (Newsom, 1978).

This review identifies a number of basic issues and concerns which formed the basis for the construction of the questionnaire and the analysis of the data.

CHAPTER II

THE LIGHT AND ILLUSION WORKSHOP: ORIGIN, SETTING, AND OPERATION

In this chapter, the origin, setting, and operation of the Light and Illusion Workshop,[1] its aims and objectives, printed guide material, and other assistance to visiting teachers and pupils will be described. The description is based on the Vancouver School Board[2] draft report on Light and Illusion and on personal observations.

The Light and Illusion workshop was the product of collaboration between the Vancouver school system and the Arts and Sciences Centre, an organization devoted to the development of informal learning facilities and experiences. Similar cooperative efforts have been reported in the literature. Newsom's studies (1978) of the educational role of museums have shown that the most successful programs are those which are based on close and continuing relations with the local school systems. Danilov (1976) states that science and technology centres have broadened the educational roles of museums. They have made educational programming an integral part of museum operations, frequently in cooperation with local school systems, and have expanded the cultural scope of their activities, sometimes beyond science and technology. Light and

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[1]Throughout the remainder of this study, the Light and Illusion Workshop will be referred to as "Light and Illusion."

[2]The Vancouver School Board will hereafter be referred to as the "VSB".

Illusion may represent the first in a series of outreach programs offered by the Arts and Sciences Centre of Vancouver.

Light and Illusion operated for nine months during school hours, from October 1980 to June 1981 and consisted of 23 participatory exhibits, 13 framed prints, and a collection of 61 slides, all relating to light and color in an interdisciplinary Art/Science approach.

The workshop was housed in a converted Home Economics room at David Thompson Secondary School in Vancouver. Class size was limited to 34 pupils per visiting group, based "on room size, number of exhibits, and for managability." One class could visit the display per session.

The workshop was made available to all VSB Elementary and Secondary schools. The VSB expected that Grades 5, 6, 8, and 11 science teachers and grades 5 through 12 art teachers would be the most frequent participants because of similarities between workshop concepts and the school curriculum.

Printed guide materials were prepared for visiting students and their teachers. A <u>Teacher's Guide</u> provided the teacher with an introduction of the display, with ideas for preparation and follow-up, a description of each exhibit, and a glossary. A <u>Student's Guide</u> summarised the exhibits and provided some ideas and suggestions for activities they could do before, during, or after the workshop. <u>A Guide to the Gallery of Paintings</u> discussed the artistic qualities of the prints, provided background information on the artist and his/her work, and guidelines for interpretation of the paintings. An information sheet on the photographic slides was also provided which identified the artist, the title of the work, and gave a brief introduction to each of the seven themes illustrated by the slide collection.[1]

In addition to the printed guide materials, other forms of assistance were made available to teachers of visiting classes. Inservice workshops were conducted by the coordinator[2] of the project at the beginning of the school year in an effort to stimulate interest and allow teachers to become familiar with the display prior to their class visit.

The "project manager/staff assistant"[3] was the one on site staff member present at the workshop for each visit. The role of the "explainer" was defined in the report as that of a "flexible resource person who could provide teachers with varying amounts of assistance in order to facilitate a productive visit." The explainer began each visit with an introduction to the workshop during which the theme and layout of the workshop exhibits were briefly described. Students were then permitted to interact with the participatory exhibits. The explainer provided assistance to students during the rest of the workshop by answering questions about exhibits. During the nine month run of Light and Illusion, 314 classes visited the workshop. Table 1 shows classes by age range and subject.[4]

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[1] The seven themes illustrated by the slide presentation included: 1. lighting effects; 2. light, time, atmosphere; 3. lighting conditions; 4. optical mixing of colours; 5. reflection of light; 6. illusion; 7. light in art, as art.

[2] The coordinator for Light and Illusion was the VSB Science Consultant.

[3] The project manager/staff assistant will be referred to in this study as the "explainer." The term "explainer" is frequently used in the literature to describe science centre staff assistants.

[4] <u>A Report on the Light and Illusion Display</u>, October 1980-June 1981.

Table 1

Class Visit Data

Elementary		Secondary	
Grades 4 and 5	49	Science 8	57
Grades 6 and 7	63	Physics 11	12
Art	15	Art	15
E.S.L.	9	E.S.L.	29
Enrichment	9	Enrichment	5
Special Education	3	Business	6
French	10	English	6
Grades 2 and 3	11	E.L.C.	15
Total	169	Total	145

CHAPTER III

THE WORKSHOP IN ACTION: REPORT OF SURVEY DATA

This study seeks to evaluate the effectiveness of the Light and Illusion Workshop. The writer sees the primary task of evaluation, as does Linn (1976) as the selection of questions that need to be answered and the adaption of evaluation skills to answer these questions, so as to improve programs, exhibits, and products to better serve the target population.

Borun (1977) states that to measure the effectiveness of museum exhibits a clear definition of workshop objectives must be made. The principle objective of "Light and Illusion" as stated in the VSB draft report, was to "stimulate interest, teach basic concepts of reflection, color mixing, perception, and the physics of lasers."[1]

In this study, teachers visiting with their classes were surveyed by questionnaire to determine to what extent these goals were achieved. As in previous studies of museum programs (Borun, 1977), the writer utilized teachers as respondents because of their familiarity with the interests and abilities of their students and because they could observe student behavior both in the exhibit hall and in the classroom following museum visits.

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[1] A Report on the Light and Illusion Display, October 1980-June 1981, p. 4.

Teachers were asked to evaluate a number of potentially meaningful variables based on the stated objectives of the workshop and on relevant questions identified from previous studies (Carlisle, 1980; Gottfried, 1979; Borun, 1977), which have been shown to affect the quality of museum education programs. From this base a series of five statements were derived to help guide the construction of the questionnaire and subsequent analysis.

1. The free choice environment created is a varied and stimulating one in which students are encouraged to explore according to their own interests;
2. the exhibits are participatory on many levels. They invite participation from casual contemplation, through the manipulation of physical materials, to encourage further study;
3. the allotted time is sufficient to permit visitor familiarization and experimentation;
4. the workshop was developed to meet the specific needs of various grade levels in both science and art;
5. the provision of an expert guide (explainer) enhances the exploratory behavior and further learning of visitors; the supplemental guide materials were designed to prepare teacher and student for the workshop and help maximize their use of it.

Teachers were requested to observe their students for at least one week following the field trip before completing the questionnaire. These latter data the writer considers most important and as Borun (1977) notes, the understanding of the nature of the long lasting effects of museum visits is one of the most important functions of museum evaluations. If this study employs many of the qualities of what is referred to as "naturalistic evaluation" which, according to Wolf (1980), relates natural behaviors and expressions to the context in which they arise and insures that persons involved in the program in question have an opportunity to describe and assess their experiences and to comment on what those experiences mean to them (op. cit.).

While such studies do not conclusively demonstrate specific learning outcomes in the cognitive domain (fact acquisition, concept and skill development), they can identify situations in which such learning can occur. In addition, naturalistic evaluations preserve the comments and impressions of participants which indicate changes in the affective domain (interest, motivation, attitudes) that may have occurred as a result of a given situation (op. cit.).

The writer has described the teacher's perception of the value of the children's experiences, rather than going to the students directly, for, as Borun states, teachers can obtain an evaluation of the effects of an informal learning experience on their students by watching their reactions over a suitable period of time.

In the development of the questionnaire, the format and individual items were reviewed by three faculty members of the Faculty of Education, University of British Columbia. On the basis of their comments and recommendations, the questionnaire was modified, printed, and distributed to teachers via VSB mail service (Appendix A). Although 314 classes visited "Light and Illusion," the target sample consisted of the 150 Vancouver School District teachers who visited the workshop with their students on one or more occasions. Ninety-four questionnaires (69%) of the 150 sent out were returned. This response rate compares favorably with the 30% considered to be an excellent return for mail-back questionnaires (Borun, 1977).

The survey was conducted over a three month period from April to June, 1981. Teachers who did not respond to the first questionnaire were sent a second copy and a follow-up phone call was made to encourage their participation.

The questionnaire consisted of 19 multiple choice items, two subjective questions and one semantic differential item. The first page of the questionnaire consisted of five questions designed to produce a profile of the visiting classes, as this information was considered essential in the analysis of the data.

Respondents were also requested to add their personal comments regarding their choice of answers to the objective questions. The additional comments were requested so that the teachers would have an opportunity to identify dimensions of the experience beyond those identified in the questionnaire items. In addition, teachers were requested to score the workshop experience on a semantic differential scale designed to measure the ability of a particular experience to stimulate or arouse interest in an observer or participant (Mehrabian, 1974).

The survey data were hand tabulated and percentage responses were calculated for each item of the questionnaire. This simple analysis indicating percentage responses for each individual statement is an effective measure of opinion (Best, 1970). A summary of written comments made by teachers is also included as the majority of teachers commented on the operation of the workshop, offered suggestions for improving the existing format, and identified topics for future programmes.

Questionnaire Response Report

Item 1: What grade level did you bring to the workshop?

Grade level	Primary 1,2	3	Intermediate 4	5	6	7	Secondary 8	9	11	Total
Number of classes	7	3	10	25	17	17	22	1	9	111
Percentage of Total	6	3	9	23	15	15	20	1	8	100

It should be noted that "Light and Illusion" was originally planned for Grade 5, 8, and 11 students; visits by other grades were also permitted. The total number of classes indicated in Item 1 (111) exceeded the total responses for other questions items (94) because some visits included mixed classes of different grade levels. The data indicate that more elementary than secondary teachers chose to visit Light and Illusion.

Item 2: Which of these describes your class?

Subject Area	Number of Classes	Percentage of Total
Science	51	54
General	16	17
Eng. as a sec. lang.	10	11
Art and science	4	7
Enrichment	4	4
Art	3	3
English	3	3
Learn. Assist. Centre	1	< 1
General Business 12	1	< 1
French Immersion	1	< 1
Total	94	100

Item 3: How many students were in the class which attended the workshop?

Class Size	under 10	11-15	16-20	21-25	26-30	over 30	Total
Number of classes	3	3	14	31	31	13	95
Percentage of total	< 3	< 3	15	33	33	14	100

Item 4: How many field trips away from your school will you take with this class during the school year 1980-81?

Number of Field Trips	1	2	3	4	5	more than 5	Total
Number of classes	17	7	26	16	10	18	94
Percentage of total	18	7	28	17	11	19	100

Item 5: What was the purpose of the visit?

Purpose	Number of Teacher Responses	Percentage of Total
Review work studied in class	21	18
Provide enrichment	80	67
Introduce a new unit	14	12
Teach core subject matter	4	3
Total	119	100

Two teachers stated that the purpose of their visit was to arouse interest and stimulate curiosity. One teacher reported the purpose of the field trip was for "students to see material related to their curriculum and enjoy themselves." The total number of responses (119) exceeded the number of replies (94) because some teachers indicated more than one purpose for their class visit.

Item 6: Was the time allocated for your students' visit sufficient?

Response	Number of Classes	Percentage of Total
Time allocated was sufficient	90	96
Time allocated was not sufficient	4	4
Undecided	0	0
Total	94	100

Teachers who stated that there was insufficient time for the visit also commented that their classes were so large that not all students were able to see all of the exhibits in the allotted time period.

Item 7: Did this workshop meet the original expectations you had for yourself?

Response	Frequency	Percentage of Total
Yes	84	90
No	7	7
Undecided	3	3
Total	94	100

The majority of the written comments (8%) indicated that the workshop "turned out better than expected." Teachers reported that their expectations about the workshop were based upon comments from colleagues and the preliminary literature (teachers and students guides) distributed prior to the class visit. One teacher expressed disappointment because of the lack of formal teaching and structure during the workshop period.

Item 8: Did this workshop meet the original expectations you had for your students?

Response	Frequency	Percentage of Total
Yes	84	90
No	3	3
Undecided	7	7
Total	94	100

Although few teachers (7%) indicated that they were undecided, it is suspected that this question may have caused some confusion in the minds of the respondents. For example, two teachers stated in their written comments that they could not understand the difference between questions 7 and 8.

Item 9: In what ways did this workshop experience differ from what you could provide in your classroom?

A significant number of teachers (34%) indicated that they lacked the financial and technical resources to present materials in their classrooms such as those in Light and Illusion. In all 27% cited a lack of available equipment while 7% stated that there was little opportunity for hands-on work in the classroom.

Item 10: How would you rate the overall value of this workshop?

Response	Frequency	Percentage of Total
Excellent	61	65
Good	31	33
Fair	2	2
Poor	0	0
Total	94	100

Further examination of response to this item shows that 63% of elementary teachers rated the workshop excellent, 50% of secondary teachers rated the workshop as excellent.

Item 11: Were the exhibits appropriate for the age level of your class?

Response	Frequency	Percentage of Total
Yes	86	91
No	3	3
Undecided	5	6
Total	94	100

In written responses to this item, 16% of teachers reported that the workshop exhibits were appropriate for their classes because they were participatory. Five percent of the respondents (grade 4, 5, 6 teachers) reported that the "exhibit theory was too complex for their students to understand." Three percent of the responses stated that the exhibits were appropriate because they "related to the classroom curriculum." One grade 11 teacher commented that the workshop was "appropriate for the first visit, but a little elementary for additional visits." A comment by a teacher of grades 1 and 2 was typical of those made by the few primary teachers (9%) who attended. She stated: "Although this (Light and Illusion) was designed for older, more experienced children, it provided a great deal of fun, exposure, and awareness for the younger children. The fact that they were free to try everything on their own was a great experience for them."

Item 12: Mean Information Rate Scores by Grade Level (see Appendix B)

	Grade Level		
	Primary	Intermediate	Secondary
Grade mean	6.6	12.2	9.9
N	5	43	28

The data indicated intermediate teachers thought that their students were being provided with a higher information rate (Appendix B) than did either secondary or primary teachers.

Item 13: Have you noticed any positive effects on your students as a result of your visit to the exhibition?

Response	Frequency	Percentage of Total
Yes	69	73
No	12	13
Undecided	13	14
Total	94	100

The following is a summary of comments.

Fourteen percent of the teachers (10 elementary, 3 secondary) reported enhanced comprehension of facts, concepts and vocabulary following the workshop experience. Eleven percent of teachers reported increased student interest and enthusiasm for some of the workshop concepts (e.g., lasers, light, illusions). Eight percent made reference to the students' increased ability to apply this information to everyday life experiences.

Four elementary and two secondary teachers stated that students became motivated to pursue library research in depth and science-fair type of projects related to workshop topics. Six teachers reported that the most noticeable effect of the workshop was the general improvement in the tone and level of student discussion about science-related topics in the classroom.

Item 14: Have you noticed any negative effects on your students as a result of your visit to the exhibition?

Response	Frequency	Percentage of Total
Yes	1	1
No	86	91
Undecided	7	8
Total	94	100

Only one teacher (physics 11) reported a negative effect resulting from the workshop visit, stating that "some students (a minority) were bored with the workshop."

Item 15: Do you think that the printed guide material provided was appropriate for your class?

Response	Frequency	Percentage of Total
Yes	70	74
No	16	17
Undecided	8	9
Total	94	100

As already stated, the printed guides were developed to assist both teachers and students to prepare for the workshop. One comment stated: "I was pleased to receive the material so I knew what to expect and was able to prepare the class for the concepts displayed." Eight elementary and one secondary teacher thought that the conceptual and reading level of the materials was too high for the students. However, a few teachers (8%) wrote that the student printed materials were of more use to them as aids in preparing the class for the workshop rather than as materials to be used by the students directly.

Item 16: Do you think that the assistance provided by the explainers was appropriate to your class?

Response	Frequency	Percentage of Total
Yes	87	93
No	6	6
Undecided	1	1
Total	94	100

The importance of trained onsite assistants (explainers) to the success of the workshop is indicated by the high rating given to the role of the explainer (93%) in comparison to the rating given to the printed guide material (70%). The following is a sample of the numerous comments on the assistance provided by the explainer: "We had an excellent explainer who found almost immediately the level of understanding with these students." "The explainer was very helpful not only in explaining but transferring her enthusiasm to her students." "The lady in charge was able to explain everything that the children wished to know at the correct level."

The principle explainer was onsite for 90% of class visits. At other times a variety of substitutes were available. Three teachers thought that there should be additional explainers stationed at various displays to assist the students' interaction with the exhibits. Three teachers suggested that "not enough direction" was provided during the workshop. One remarked ". . . thus undirected, young students wander from exhibit to exhibit, 'playing at learning' rather than 'learning while playing'."

Item 17: Did you involve your students in any follow-up activities in the classroom after the workshop?

Response	Frequency	Percentage of Total
Yes	70	74
No	24	26
Total	94	100

Class discussion about the workshop activities and student experimentation were the two most frequently mentioned follow-up activities (74%) by both elementary and secondary teachers. Other student activities considered as follow-up were: the construction of a periscope, mirror experiments, and drawing of optical illusions. Only four teachers clearly categorized the follow-up activities as art related, reflecting the strong science bias in the sample.

Item 18: Did the follow-up activities specifically suggested in the guidebook help you extend the workshop experiences in the classroom?

Response	Frequency	Percentage of Total
Yes	26	29
No	31	34
Undecided	34	37
Total	91	100

Although 74% of the respondents indicated some type of follow-up activity resulted from the workshop, the guidebook was used as a resource by only 29% of those teachers.

Item 19: If it were possible, would you bring the <u>same</u> class back to this workshop?

Response	Frequency	Percentage of Total
Yes	49	52
No	31	33
Undecided	14	15
Total	94	100

A significant number of teachers (19%) reported that a single visit was adequate and that a repeat visit would be "too repetitive," "unnecessary," or "boring." Eleven percent of the teachers indicated they would return with the same class for a more comprehensive study of specific topics (e.g., projects involving the color wall).

Item 20: If it were possible, would you bring <u>another</u> class to this workshop?

Response	Frequency	Percentage of Total
Yes	91	97
No	1	1
Undecided	2	2
Total	94	100

Item 21: How best could your students be prepared for a workshop such as this?

This item elicited the greatest number of written responses. Twenty-one percent prepared students for Light and Illusion by making them familiar with curriculum topics related to the workshop. Other teachers (30%) emphasized the importance of learning about the exhibits themselves by using the prepared guide books sent to schools prior to the actual field trip. Four percent of teachers thought that audio visual materials such as film strips about the workshop should have been provided for student learning before their visit. A preliminary visit to the workshop by the teacher was mentioned by 9% of the respondents. Others (9%) thought that a preliminary visit by the teacher to the workshop would have been useful.

Item 22: Would you like your class to attend workshops of this type on other topics?

Response	Frequency	Percentage of Total
Yes	88	94
No	1	1
Undecided	5	5
Total	94	100

Seven percent of the teachers indicated that any workshop of the 'hands-on' variety would be a worthwhile experience for students. The following is a typical comment: "Anything that takes learning away from books and into the kids' hands is bound to be more interesting and will be retained." Five percent (all) elementary teachers requested future workshops on any 'science topic.'

Specific suggestions for future workshop topics were: photography, film making, art and perspective, health (fitness, nutrition), earth science history, forces and energy, sound, and biology.

CHAPTER IV

AN ANALYSIS AND DISCUSSION OF THE WORKSHOP EXPERIENCE AS REPORTED BY TEACHERS OF VISITING CLASSES

In this chapter, the value of the workshop (as reported by teachers in the questionnaire responses) is examined. The point of view is taken that Light and Illusion is an example of an informal learning experience, and is thus characterized by free choice, lack of prerequisites and credentials, heterogeneity of learner groups in background, interests, and social interaction.

In lieu of additional statistical analysis, the percentage responses, together with written comments provided by teachers responding to the questionnaire, is examined to make evident what teachers consider to be workshop strengths, weaknesses, and features which contribute to learning in the informal learning environment.

The questionnaire was constructed to elicit responses to specific questions but also to encourage additional written comments by teachers. The analysis therefore, is based on a review of the questionnaire data together with reference to the literature. By this chosen methodology those issues and concerns which could not be anticipated in advance are made evident.

Comments which indicate the point of view of at least 10% of the respondents will be considered as significant, although comments representing differing points of view will also be presented. Finally, various dilemmas, paradoxes and contradictions made obvious by a review of the data will be discussed and the writer's viewpoint will be presented.

1. Workshop Strengths

If popularity is an indication of success, then Light and Illusion was very successful. Ninety-eight percent of visiting teachers rated the workshop as either "excellent" or "good." Originally planned for grades 5, 8, and 11 art and science classes, the workshop also hosted students in languages, enrichment, special needs, business, and primary classes. The suitability of the experience is indicated by the fact that 90% of the teachers attending reported the workshop met their expectations, and over 70% indicated that the exhibits, guide materials, and on site assistance were appropriate for their classes.

Ten percent of teachers stated that the workshop was a learning experience for them as well as for their students. Twenty-eight percent stated that the workshop gave students a rare opportunity to work with very expensive, sophisticated equipment which would "never" be available in a regular classroom. Thus, this workshop provided many teachers with an opportunity to observe the effects of an unusual learning situation on their students' behavior.

Another strength reported by teachers (11%) was the opportunity for students to receive more individual attention than normally available in the regular classroom. Since students had freedom to circulate at will through the workshop, the explainer and teacher were free to offer assistance to individual students or small groups.

Eleven percent of visiting teachers stated they would bring the same class back for another visit, while 97% stated they would bring other classes to the workshop. Thus, the workshop may have provided an important break from the routine of day to day class work. However, teachers may also have considered the workshop to be small enough for their students to make use of in just one visit.

Twenty-seven percent of reporting teachers indicated that Light and Illusion was a "novel" experience both in type and in location. These data parallel the literature--novelty stimulates both curiosity and interest and encourages exploratory behavior. Thirty-eight percent of teachers also reported that students had more interest in learning about science in the classroom following the workshop experience. So, both in terms of suitability and benefit derived, the workshop can be considered a positive and rewarding experience.

2. Workshop Weaknesses

Workshop weaknesses are considered to be those features described by teachers as inappropriate for their classes. In this context, the major problems reported by visiting teachers were identified as incomplete or inappropriate assistance during the workshop, or incomplete or inappropriate materials sent to them prior to the workshop.

However, it should be noted that complaints were few in relation to the positive comments made about the workshop. Six percent of the teachers would have preferred an additional explainer to assist students, 13% indicated that the guide material was too complex for their students, and a few teachers (4%) were disappointed at the 'lack of teaching' during the workshop. Four percent of the teachers would have appreciated some audiovisual material to explain exhibit functions before the visit, and 12% would have preferred a visit from the explainer to the classroom to assist preparation. Such comments suggest that teachers may be 'missing the point' in regard to the nature of informal learning situations. They may regard Light and Illusion as a replication of classroom activities, while in fact the workshop planners attempt to develop a different learning environment. The misconception would seem to lie in the communication of the goals and expectations of the workshop to the teacher through the printed guide materials. Although one objective of the workshop was stated to be the acquisition of knowledge about light and illusions, few indications of cognitive gains were reported. However, it is doubtful if this should be considered a weakness of the workshop in light of reports in the literature that cognitive learning in informal environments are poorly understood and are difficult to measure using conventional testing procedures.

3. Novelty in the Informal Learning Environment

In this study, teachers were requested to describe how the workshop experience differed from what was offered in the classroom. In this section, it will be shown that teachers considered Light and Illusion to be a novel experience for their students which stimulated curiosity and encouraged exploratory behavior, thus meeting a major objective which the coordinators had formulated for the workshop. This finding parallels studies in the literature which indicate novel learning experiences are a natural and necessary part of the learning process.

Kimche (1978) states that people go to science centres to satisfy their curiosity about science and to experience new and interesting phenomena. Borun (1977) notes that teachers value a class visit to a science centre as a means to stimulate children to seek further information. Hebb (1978) maintains that the need for normal stimulation of a varied environment is fundamental. Kaplan (1980) has described the biological basis of the effect of novel stimuli on behavior and suggests that curiosity is aroused by novel stimuli and that curiosity and exploration encourage the acquisition and utilization of information likely to foster survival in an information-oriented organism.

Kaufman (1971) states that Piaget has observed that (typical) behavior of primary aged children, at "pre-operational levels," consists mainly of random observation and naming of concrete objects. For children of elementary age, however, Piaget suggests that exploration of novel situations is more purposeful and is used to establish a cognitive framework for the classification of concrete objects.

In this study 27% of reporting teachers identified three novel features of the workshop. They noted:

1. the availability of sophisticated equipment and materials exceeded that of the classroom. Teachers commented: "(exhibit) technology was far more sophisticated than the classroom equipment"; "it provided a much greater scope of materials"; "fancy equipment and examples of light experiments are completely beyond the resources of the elementary classroom"; "good opportunity to use materials that would be difficult to set up in the regular classroom."
2. the opportunity to participate in interactive learning activities exceeded that of the classroom. Teachers commented: "this kind of 'sensory' approach would be nearly impossible to duplicate in the classroom"; "obviously a classroom experience is very limited compared to the wealth of 'hands-on' activities"; "children could touch and experience materials we cannot have in the classroom";

"this workshop gave the students a first-hand look and feel for the things we had been discussing."

3. the opportunity for students to move freely in the workshop exceeded that of the classroom. Teachers commented: "the workshop allowed students to move freely which they enjoyed"; "the students could work by themselves"; "the children had more chance to experiment on their own with physical instruments."

A significant number of teachers (23%) reported that the allotted time for the class visit was almost totally taken up with student exploration of the participatory workshop exhibits. The teachers' observations parallel those reported in the literature which indicate that children's curiosity stimulates physical activity. As Peterson (1979) states:

> through coordination of sense organs with physical movement (referred to as sensory motor responses), children approach novel objects they encounter in their environment and reach out to explore by touching, tasting, smelling, listening, looking and perhaps by reorganizing parts of these objects in some way.

Teachers provided other indications that the students found the experience more interesting than the classroom setting. A significant number (19%) of teachers stated that students asked more questions about the exhibits than they asked about regular classroom assignments. This increased rate of questioning Gottfried (1979) considers to be an extension of exploratory behavior in a novel environment. Additionally, 38% of visiting teachers reported that students "were more interested in learning about science" in the classroom following the workshop than they were before the field trip.

So as to obtain further indication of how interesting teachers and their students considered Light and Illusion to be, teachers were requested to complete a semantic differential scale in the questionnaire which measures information rate (Appendix B). Studies of information indicate that for any situation, an optimum level of multisensory stimulation exists which produces maximum arousal or interest. However, the use of information rate to measure interest levels is still in its infancy and the literature does not clearly indicate how such scores should be evaluated. Indeed, very few comparisons are available to enable evaluation of the data produced by this study. One study (Mehrabian, 1974) does describe a mean information rate of -2.2 for a series of audiovisual presentations which required little active participation by the viewer-subjects.

In comparison, the present study shows a mean score of 9.6. Based on this single comparison, it might be suggested that Light and Illusion is a more interesting experience than passive observation of classroom audiovisual presentations. Indeed, it is likely that the information rate score for Light and Illusion is higher than most classroom activities. However, no data exist at this time to support this contention.

This present study also shows that the workshop was scored higher on the Semantic Differential Scale by elementary teachers (12.2) than by secondary teachers (9.9). This difference in scores may indicate elementary teachers found Light and Illusion to be a more interesting experience than did secondary teachers, since information rate is defined as a measure of interest or arousal level. Since studies in the literature indicate interest is stimulated by novelty and complexity, this writer suggests that the difference in information rate scores may also indicate that elementary teachers considered the novelty and complexity of Light and Illusion of more value than did secondary teachers.

One would be unwilling to speculate about the significance of this finding. However, it is interesting to note that this finding parallels studies in the literature (Borun, 1977) which suggest that informal learning experiences such as provided by Light and Illusion are more popular with elementary aged students than with any other age group evaluated.

In addition, Peterson (1979) states that "fewer opportunities actually exist in the classroom for the expression of curiosity than existed in the sixties" and implies that this deficiency results from a renewed "emphasis on the 3-R's" and the "development of instruction which rarely includes performance objectives which pertain to the expression of curiosity." It is possible that this same deficiency could also exist in certain elementary British Columbia classrooms. The "British Columbia Elementary Science Interim Guide" lists three programs authorized for use in British Columbia elementary science classrooms: Material Based Units, which emphasizes "involvement of students in scientific activities and explorations" and two other programs, Space, Time, Energy and Matter (STEM) and Exploring Science, both of which are described by the guide as "textbook programs." Currently, most teachers are encouraged to use the two "textbook programs" (STEM and Exploring Science) in their classrooms (Carlisle, 1981).

However, this study indicates that other programs, such as the Material Based Units, may better meet what Peterson (1975) states as the "need for a wider variety of conditions under which pupils are permitted to explore in order to accommodate what appear to be differential preferences or modes of expressing curiosity among children of elementary school age."

4. Active Participation in the Learning Process

In this study, teachers were asked to comment on the appropriateness to their students of the preparatory and follow-up materials, the workshop exhibits, and on site staff assistance. It has been shown that teachers considered their students to have had more interactive activities in the workshop than in the regular classroom, that these interactive activities were a positive feature of the workshop, and that interactive activities occurred in the classroom following the workshop. These are significant outcomes which correspond to studies in the literature which indicate that active participation contributes to learning in children.

Thier and Linn (1976) state that the value of active participation in the learning process has been demonstrated by Piaget and Inhelder whose theories on how children learn are the basis of some science curriculum developments projects (e.g., Science 5-13, Science Curriculum Improvement Study). Inhelder states that cognitive development stems essentially from an interaction between the subject and the environment and that learning is a by-product of one's interaction with his environment. Indeed, many psychologists, including Kaufman (1971) define learning as a change of behavior brought about by experience. Thier and Linn (1976) state that when individuals interact with physical materials in an informal learning environment they gather a different kind of evidence than when they hear or read about something. The interactive learner manipulates objects, explores variables and utilizes the evidence obtained in reaching a personal conclusion about the situation investigated. In the museum setting, Screven (1976) found that interactive devices tended to increase visitor motivation resulting in more time spent attending to an exhibit and greater effort to master content

(Screven, 1976). Shettle (1973) also reports participation increases the acquisition and retention of information.

This study shows that active participation was regarded by 38% of visiting teachers to be a 'significant' part of the workshop experience, although only 10% of teachers reported observable cognitive gains (e.g., acquisition of facts and concepts)in their students following the workshop experience. This low percentage of teachers recording cognitive gains is puzzling. However, Screven (1976) states that learning cannot be directly observed. Learning must be inferred, usually from observed changes, in what an individual can do before and after exposure to an informal learning situation. This study would include not only the cognitive gains reported by teachers to be learning outcomes but also other outcomes such as increased interest in workshop topics and the emergence of new activities such as the construction of simple pieces of apparatus, displays, etc. In fact, a variety of activities described as new and unique for their classes were reported by teachers to have occurred in the classroom following the workshop.

Forty-four percent of visiting teachers reported their students constructed simple pieces of scientific equipment using principles illustrated by the exhibits. The most common piece of apparatus to be constructed in the classroom (10% of visiting classes) was a simple periscope made out of a variety of materials such as cardboard tubes and milk cartons. One particularly active grade 5 class followed the field trip with such new classroom activities as the construction of simple tube periscopes, paint mixing to produce a variety of new pigments and hues, and also the drawing of original optical illusions.

Thus this study indicates a variety of learning outcomes of the informal learning experiences in addition to the cognitive gains reported by teachers. It is anticipated that the range of learning outcomes is much wider than those reported. No doubt with additional experience a lexicon of descriptors of learning outcomes could be developed. This lexicon would be important, not only for the teachers but also the exhibit planners.

5. Choice and Guidance in the Informal Learning Environment

Teachers visiting Light and Illusion with their classes indicated "free choice" was a significant feature of the workshop experience. Thirty-four percent of the teachers reported that visiting students manipulated exhibits of their choice and 30% of the teachers reported that "free choice" increased the variety of learning opportunities for their students. Eleven percent of visiting teachers reported that students "did not see all of the exhibits because of the time spent with specific exhibits of their choice," although the majority of teachers also reported that the time available in the workshop for their class was appropriate. All these findings are significant and they parallel reports in the literature, as in Laetsch (1980), who states, "free choice is basic to what can happen in informal learning environments." Laetsch has also reported science centre visitors "shop around" before finding an interesting exhibit where they will spend most of their time. Other studies (Gottfried, 1979; Bowen, 1977) indicate that choice of desired learning materials, procedures, pace, and sequence of activities encourages exploratory behavior which is a natural and necessary prerequisite to analytical learning.

Oppenheimer (1972) states that:

> Individuals visit museums in different fashions, but frequently they first survey what is there and later return to selected sections to become more deeply involved. Their second look is more deliberate and enables the visitor to appreciate the details of the exhibits as well as their relationship to one another and to the general landscape. By presenting a multiplicity of examples, in a variety of contacts, of an abstraction such as wave motion or energy or randomness, the museum can build up the visitor's intuitive familiarity with such concepts.

Hawkins (1965) states that when the mind is involved with abstractions which will lead to physical comprehension, "all of us must cross the line between ignorance and insight many times before we truly understand."

The Light and Illusion offered three forms of guidance for visiting students: printed guide materials, an on site explainer, and exhibit graphics. Seventy percent of visiting teachers found the guide materials provided prior to the field trip appropriate for their classes. One teacher commented, "I was pleased to receive the material so I knew what to expect and was able to prepare the class for the concepts displayed." However, 9% of the teachers suggested the guide materials "could have provided more detail as explanation for the various phenomena" and "could have included more information on the principles of science." A few teachers (4%) commented on exhibit graphics. Three teachers stated the graphics were "too complicated" and "confusing" for their students. One stated that the graphics "did not have enough information to explain the exhibits." This comment is interesting as a study by Eason (1976) indicates that "few visitors bother to read exhibit graphics before interacting with the exhibits," and "most visitors read graphics only if they cannot first obtain a meaningful response from an exhibit by trial and error."

Eighty-seven percent of the reporting teachers indicated that the assistance provided by the explainer was appropriate for their classes. Eleven percent of the teachers indicated that the most important role of the explainer was that of "adapting the workshop experience to the interests and grade level of each visiting class." However, 12% of reporting teachers expressed a desire for more structured learning. For example, teachers commented, "a linear layout would have assisted in class management; the children scattered around the room and missed many important features of the exhibits," and "there was not enough direction, the explainers did not take the initiative in explaining exhibits." Teachers may express a preference for a more structured learning environment than that offered by Light and Illusion because they are accustomed to teacher-centred learning activities in the classroom. Research shows that two-thirds of the traditional classroom talk is done by the teacher, of which 50% consists of presenting information, opinions, directions, and criticisms (Bowyer, 1978). In addition, there are studies in the literature which support teacher structured learning and studies which support free choice (student structured) learning.

Research by Thier and Linn (1976) show that an introduction to science concepts assists children to structure their experiences in a free choice situation. They also show that a "structured introduction to each set of equipment is useful." Okey (1978) notes Ausubel's suggestion that "relevant and inclusive" introductory material, which he calls "organizers," should be presented prior to a learning task to facilitate the acquisition and retention of meaningful material. However, Hawkins (1965) has stated that a learning experience should begin with a period of free and unguided exploratory work, which he calls "messing about" during which children are given materials and equipment and are allowed to construct, test, probe, and experiment without superimposed questions or instructions. Hawkins also states that exploratory work in the classroom provides sufficient acquaintance with phenomena against which a more analytical set of knowledge can take form and make sense.

Kaufman (1971) refers to Piaget and Inhelder's belief that an important factor in the acquisition of knowledge is experience which is in conflict with the child's predictions for the outcome for a particular event. For example, 30% of the Light and Illusion exhibits illustrate various optical illusions which Oppenheimer (1972) describes as experiences which present ambiguous or conflicting cues, forcing the viewer to search for a plausible hypothesis so that he can understand what he is seeing. Bruner (1966) also values perceptual conflict and provides contrasts and incongruities in order to get the child, because of his discomfort, to try to resolve the disequilibrium by making some discovery. To Bruner (1966) discovery is an accommodation to achieve a new balance by modifying the previous cognitive structure. These educators see the child as the principle actor in his own education.

This study has shown that a majority of the teachers found the various forms of guidance available for students at Light and Illusion appropriate for their classes. This is a significant finding because the workshop is a "free choice" informal learning experience which differs from teacher centred formal learning environments of most classrooms, and recent research shows that "free choice" situations assist effective learning in children. However, this study also suggests that teachers may value "free choice" experiences for reasons (e.g., increasing student interest) other than those stressed in the literature and thus more research is required to identify and examine outcomes of free choice informal learning experiences considered desirable to classroom teachers. As Coombs (1978) states, "the challenge facing educators is to develop the full range of each individual's capacities and place control of the learning process as much as feasible in the student's hands."

CHAPTER V

LIGHT AND ILLUSION: PERSONAL OBSERVATIONS

1. The Integration of Art and Science

The printed guide material for Light and Illusion describes the workshop as an "integration of the arts and sciences." However, this study has shown that the workshop did not encourage teachers to present the study of art and study of science from an integrated perspective. This contention is based upon evidence from data which indicate that following the workshop visit, teachers continued to classify objects and activities in the learning environment as either "art" or "science." Teachers classified the majority of the exhibits as "science"; other teachers labelled displays of prints and a slide production as examples of "art." The majority of the teachers visiting Light and Illusion (71%) described their classes either as "science" or as a general class visiting as "part of the science unit." A significant number of teachers (42%) also classified the behaviors observed during the workshop and in the classroom after the field trip as science-related. Follow-up activities in the classroom, such as discussions, library research, and project building were almost exclusively described as "science activities."

Teachers indicated that most of the allotted time at the workshop for each class was taken up with exploratory activities. This exploratory activity of the exhibits "provides an extremely natural way of linking art and science since both of these influence the way in which people perceive their environment" (Oppenheimer, 1972). Yet students did not talk of arts and science nor did their teachers.

It is possible that the time made available for each class was too short to permit students to progress much beyond the exploration of a novel environment to consider the kind of complex interrelationships inherent in the concept of an integration of art and science. Perhaps the problem of perceiving the unity of art and science lies with the teacher and not with the student. Hurd (1973) states that children under the age of eleven (which constitutes the majority of visiting students) "perceive their environment as a unity and not as a collection of phenomena separated into subject compartments." Chisman (1973) thinks that the problems of introducing integrated science (and supposedly other integrated schemes) are particularly difficult for teachers. He states that science teachers are "trained in a subject discipline approach" and "to bring about change involves a major task of retraining and reorientation." Finally, it is also possible that teachers, accustomed to specialized subject areas of learning, perceive an integrative theme in art and science activities to be a weakness rather than a strength, and therefore chose to de-emphasize that aspect of the workshop experience. Indeed, in our society the sciences and the arts are seen to be separate and their proponents as belonging to separate cultures.

2. Age Level Appropriateness

This study shows that elementary teachers considered Light and Illusion to be more appropriate for their students than did secondary teachers. The workshop was rated as excellent by 58% of the elementary teachers as compared to 47% of the secondary teachers. The study also shows that elementary teachers considered Light and Illusion more interesting than did secondary teachers. Elementary teachers rated the workshop higher on an information rate scale than did secondary teachers. One possible interpretation of the difference in information rate scores is that the novel experiences offered by the workshop lacked the complexity required to stimulate the adolescent mind. One might also speculate that older students saw the workshop as less complex, less novel, than their younger counterparts. It is also possible that the workshop appealed more to elementary classes because the sensory stimulation provided by novel exploratory activities with concrete objects was better suited to elementary students. For secondary pupils maybe the experience was less novel, less complex, and lacked extension into more abstract, symbolic content. Piaget would contend that younger children prefer to operate at the concrete level of thought while adolescents progressively prefer more abstract thought and arguments.

The Light and Illusion exhibits are typical of those found in science centres and similar institutions of informal learning. Borun (1977) has reviewed many studies which indicate that such facilities commonly appeal more to elementary-aged students than to secondary students. Perhaps exhibits like those used in Light and Illusion would appeal more to adolescents if they offered greater flexibility in use of exhibit components with extensions into other information sources, such as supplementary text material, exhibit graphics, and printed exhibit guides.

Teachers also commented that preparatory materials to be used by students sent by the workshop prior to the visit were used more by the teachers themselves to assist in lesson preparation. Thus many students were provided with a unique learning resource only after it was "packaged" into a form considered appropriate by the teacher.

In light of such evidence, it is not surprising that teachers appear to view the value of informal learning to be less than the value of formal learning experiences, as discussed in another section of this study. Nor should there be much surprise at the almost complete lack of reference by teachers to one of the major themes of the workshop, the integration of the arts and sciences.

This study, as others (Newsom, 1978) identifies areas of disagreement between teachers and workshop staff regarding the form of guidance most appropriate for students in informal learning environments. This disagreement may result from a lack of understanding of each other's goals and needs, which suggests that more communication between teachers and staff of informal learning environments may assist in the planning of informal learning experiences more satisfactory to both parties.

3. Teachers as Learners

This study indicates that teachers tried to adapt the workshop experience to fit the demands of the school curriculum and the routine of the classroom. Teachers commented (17%) that the workshop was a 'learning experience' for them as it provided an opportunity to observe their students in action in an informal learning environment. Newsom (1978) also reports that teachers of classes participating in educational programs at the Exploratorium get as much out of the experience as do the children and that the Exploratorium course introduces them to some new concepts as well as some new ways to teach them. However, 11% of teachers reported that they wanted more than the one explainer made available for each class, to assist individuals or small groups of students so that they would "have a better understanding of the exhibits." Such comments suggest that teachers preferred a more structured learning situation than what was offered by the Light and Illusion workshop. Alexander (1980) also reports how social studies teachers use museums and notes that teachers worry about the relaxation of discipline in the museum, the tendency of museum instructors to move too fast or to use terms that are unfamiliar to the children, or the failure of museum educators or docents to try to understand the learning process in children.

4. Single Visits

The Light and Illusion workshop was planned as a single visit for elementary and secondary school classes, although return visits were permitted if requested by the classroom teacher. This study has shown that teachers prefer one-shot field trips for their students.

The desire for single visits apparently does not indicate dissatisfaction with field-trips or with the Light and Illusion workshop. Ninety-six percent of teachers visiting Light and Illusion rated the workshop good or excellent. Ninety-seven percent of teachers visiting Light and Illusion indicated a desire to return to the workshop with another class. Fewer teachers (11%) stated they would want to bring the same class back to the workshop for a repeat visit. These teachers commented that a repeat visit would be "unnecessary," "boring," or "unnecessarily repetitious." In addition, over two-thirds of the visiting teachers reported some form of positive changes in classroom behavior following the single workshop visit and 27% of the reporting teachers stated that "novelty" was a "significant feature of the workshop" and offered "hands-on activities" and "sophisticated equipment" which was not available in the classroom.

The emphasis which teachers have placed on novelty suggests that field trips may be valued as novel experiences which increase student interest and as a change from the normal classroom environment. Perhaps teachers perceive repeat visits to be less novel and therefore less interesting for their students. This contention is supported by studies in the literature. Laetsch (1980) reports that most teachers view science centre field trips as enrichment activities with special emphasis on social interaction in a new environment and not as a continuation of classroom learning. Sidul (1976) states that the major justification for field trips should be the unique outcomes that arise from the field trip setting (for example, interest, motivation, psychological rejuvination for teachers and students).

However, as discussed elsewhere in this paper, novelty can provide an important stimulus to learning. It is possible that (because they are novel experiences) single field trip experiences subsequently improve student learning in the classroom. This statement is supported by the fact that over two-thirds of the visiting teachers reported some form of positive changes in the classroom behavior following the workshop. To summarize comments reported elsewhere in this study, the interest generated during the workshop may carry over into the classroom as a motivational factor which spurred discussion, library research, laboratory experimentation and project building. These are significant outcomes which suggest "one-shot" field trips may contribute to learning and indicate more research is required to identify other ways teachers can use such experiences for their students.

5. The Explainer's/Organizer's View

In this section of the study, the draft report[1] on Light and Illusion is reviewed to identify the strengths and weaknesses of the workshop as perceived by staff and organizers, and to compare the perceptions of staff and organizers with perceptions of the visiting teachers described elsewhere in this study. With this comparison it is intended to obtain another view of the effectiveness of the workshop as an informal learning experience.

The principal objectives of the workshop are described in the report as "the use of exhibits to stimulate interest, teach basic concepts, and extend and enrich student knowledge." The report indicates that some of the above objectives have been met more completely than others. Both this study and those reported in the literature find little evidence for student learning of basic concepts in informal learning environment. However, the stimulation of student interest through interaction with sophisticated participatory exhibits was noted in the VSB report and in this study as a major strength of the Light and Illusion experience.

Teachers' comments reported in this study correspond to the VSB report's contention that students would have benefited from more guidance from adults during the field trip. However, some differences exist between teachers and staff as to how that guidance could best be provided. Teachers reported that additional explainers were needed or that explainers

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[1]The Vancouver School Board (VSB) draft report on Light and Illusion was prepared by the workshop staff and describes the operation and outcomes of the project.

should have "spent more time explaining the exhibits to individual students." The staff, however, indicate that "it was difficult to explain the function of an exhibit unless students already understand basic principles (for example, reflection, refraction) illustrated by the exhibits." The staff also reported that the effectiveness of a workshop visit increased when the visiting teacher:

1. prepared the students in the classroom before the visit;
2. participated with the students during the workshop visit;
3. provided students with an assignment to be completed during the visit.

The comment made by staff about the desirability of providing students with "an assignment during the visit" deserves special mention. The administration of "assignments" may be described as a form of extrinsic motivation which according to the literature can conflict with the outcomes (intrinsic motivation) of the informal learning process (Kaufman, 1971). Extrinsic motivation occurs in the form of a reward of some type for the completion of a learning task. Intrinsic motivation is not directly connected to obvious external incentives. Bruner (1961) states that discovery learning frees the child from the control of extrinsic incentives and that discovery learning allows the child to achieve gratification (intrinsic motivation) from "coping with problems arising from the active manipulation of his environment." Perhaps the need perceived by staff and teachers for adult supervision to assist students to "understand" the concepts and principles which the exhibits were supposed to illustrate may indicate that the exhibits themselves do not communicate effectively to the students who use them.

Brown (1979) has stated that exhibits are the primary source of information in an informal learning environment. The frequent comments reported in this study and in the staff report regarding the need for supplemental information sources (preparation for the workshop in the classroom, additional on site explainers) may add support to the suggestion made elsewhere in this study that the exhibits themselves are deficient as learning devices. It is possible that some of the objectives of the workshop stated in the staff report were unattainable using the exhibits on display at Light and Illusion. These exhibits were borrowed from a previous exhibition which may have required exhibit designs based on objectives different from those of Light and Illusion. This contention is supported by studies in the literature which show that exhibits can produce desired learning outcomes when designed to meet carefully defined learning objectives.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In this section, data generated by the survey will be summarized and conclusions about teachers' perceptions of the value of the Light and Illusion Workshop as an informal learning experience will be drawn. Written concerns expressed by at least 10% of responding teachers have been considered as significant and thus are included in this summary. These are discussed in relation to the four dimensions (active participation, novelty, free choice, and guidance) identified in the literature which are considered important aspects of the informal learning environment. Additional dimensions identified by teachers are noted and the writer's personal observations on these dimensions are given.

1. Dimensions Identified from the Literature

A. Active Participation

From teachers' comments in response to item nine of the questionnaire, active participation was regarded by 38% of reporting visiting teachers to be a "significant part of the workshop experience." In response to items thirteen, seventeen, and eighteen of the questionnaire, 48% of visiting teachers reported that following the workshop their students constructed simple pieces of scientific equipment using principles illustrated by the exhibits. From these data it can be concluded that teachers considered the opportunities for active participation to be a positive feature of the Light and Illusion Workshop and that for some children new forms of activities emerged in the classroom following the workshop experience.

B. Novelty

In items nine and eleven of the questionnaire, 27% of reporting teachers stated that the Light and Illusion Workshop was a "novel" experience and identified three such novel features of the workshop. They noted that: 1. the availability of sophisticated equipment and materials exceeded that of the classroom; 2. the opportunity to participate in interactive learning environments exceeded that of the classroom; 3. the opportunity for students to work and move more freely in the workshop space exceeded that of the classroom.

In addition, 19% of teachers indicated that students asked more questions about the exhibits than they asked about regular classroom assignments. Further, in response to item thirteen, 38% of teachers reported that students were "more interested in learning about science in the classroom following the workshop than they were before the field trip."

In response to item twelve, elementary teachers rated the workshop higher on an information rating scale (12.2) than did secondary teachers (9.9) implying that elementary students found the Light and Illusion Workshop to be more interesting than did secondary students.

From the above data, it can be concluded that the Light and Illusion Workshop was considered by teachers to be a novel experience for their students and stimulated their curiosity.

C. Free Choice

In response to personal comments solicited in item nine, 34% of reporting teachers reported that their students manipulated exhibits of their choice and 33% of teachers who responded to items nine, eleven, and thirteen reported that free choice increased the variety of learning opportunities for their students. In response to item six, 11% commented that students did not see all of the exhibits of their choice. It can thus be concluded that teachers considered "free choice" to be a "significant" feature of the workshop experience.

D. Guidance

From the comments solicited by item sixteen, 87% of teachers emphasized that the assistance provided by the explainer was "very appropriate for their classes." Eleven percent indicated that the most important role of the explainer was that of "adapting the workshop experience to the interests and grade level of each visiting class." In response to item fifteen, 70% reported that the guide material provided prior to the field trip was appropriate for their classes. Thus it is concluded that a majority of teachers found the various forms of guidance for workshop experience to be appropriate for their classes.

2. Personal Observations on Dimensions Identified by Teachers Responding to the Survey

a. The survey did not produce data to show that teachers were encouraged by the Light and Illusion Workshop to present the study of art and science from an integrated perspective.

b. Responses to item twelve imply that elementary teachers considered Light and Illusion to be more appropriate for their students than did secondary teachers.

c. Responses to items seven, eight, nine, thirteen, and seventeen indicates that teachers appear to value informal learning experiences more as an opportunity to increase student interest than to acquire factual information.

d. Responses to items fifteen, seventeen, eighteen, and twenty-one show that teachers tried to adapt various parts of the workshop experience to fit the school curriculum and the routine of the classroom. They mentioned the printed guide materials, the interaction with exhibits, and the suggested follow-up activities.

e. In response to item twenty, teachers preferred single field trips as novel experiences which increase student interest and as a change from the normal classroom environment. Teachers appeared to perceive repeat visits to be less novel and less interesting for their students. However, the interest and activities displayed by students suggest that single field trips motivate and thus increase learning in the classroom. Additional research is required to identify other successful ways in which teachers may use single field trips for their students.

f. Responses to item sixteen implies that some exhibits themselves do not communicate effectively to the students who use them and more adult supervision beyond that offered by the workshop is needed. The Light and Illusion exhibits were borrowed from a previous exhibition which may have required exhibit designs based on objectives different from those of the Light and Illusion Workshop.

CHAPTER VII

RECOMMENDATIONS FOR FURTHER ACTION

In this section recommendations for future action are made which, according to the findings of this study, may increase the effectiveness of both the informal learning experiences and of formal learning in the classroom. In addition, a list of possible future workshop topics identified by reporting teachers will be provided.

1. Conclusion: Hands-on, free choice learning experiences are popular with teachers and students.

   Recommendations: Additional informal learning activities should continue to be offered to teachers and their students.

2. Conclusion: Novel learning experiences may increase student interest in learning and encourage exploratory behavior.

   Recommendation: That novel learning experiences be made available to students and that students be provided with opportunities to explore novel learning environments in a free choice situation.

3. Conclusion: The time allotted for each class' visit to Light and Illusion was sufficient to permit visitor familiarization and experimentation.

   Recommendation: Future informal learning experiences which are similar to Light and Illusion should adopt the schedule of time periods used for Light and Illusion.

4. Conclusion: Teachers indicated that secondary students found informal learning activities at the Light and Illusion Workshop to be less interesting than did elementary students.

Recommendation: That learning activities at the formal operations level which extend beyond which is offered by the exhibits be provided as part of informal learning experiences for secondary students.

5. Conclusion: Teachers commented that the provision of a trained guide (explainer) and printed guide materials enhances exploratory behavior and further learning of students, and assisted teachers' preparation for field trips.

Recommendation: That explainers and printed guide materials be provided to assist teachers and students in informal learning environments.

6. Conclusion: Teachers did not refer to the integration of art and science although it was a major theme of Light and Illusion.

Recommendation: Teacher inservice training should be offered to encourage the development of integrated learning activities in the classroom.

7. Conclusion: Teachers indicated interactive activities are not a regular part of classroom activity.

Recommendation: Inservice training for teachers should be encouraged to involve their students in interactive learning activities in the classroom.

8. Conclusion: Teachers preferred single field trips to repeat visits to Light and Illusion.

Recommendation: That field trips to museum workshops similar to that presented by Light and Illusion be organized around the materials and activities that can be effectively utilized in one visit. More complex workshops than currently offered by Light and Illusion should be made available to encourage multiple visits. Some suggestions offered by teachers for additional workshops in future programs are:

1) photography
2) film making
3) art and perspective
4) health (fitness, nutrition)
5) sound
6) biology
7) earth science
8) history
9) forces and motion
10) social studies
11) magnetism
12) electricity
13) evolution
14) colour

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APPENDIX A

LIGHT AND ILLUSION

TEACHER QUESTIONNAIRE

In order to evaluate the effectiveness and value of the workshop to you and to your students, we ask you for a few minutes of your time to complete this questionnaire. Please observe your students in the classroom for one school week before completing the questionnaire.

Your response is completely confidential. The data will be used only by the researcher and the resulting report will be written to guide further action. Individual teachers, schools and school districts will not be identified. The code number on the questionnaire is solely for follow-up purposes.

Please return the completed questionnaire in the self-addressed envelope by ____________________.

DEPARTMENT OF MATHEMATICS AND SCIENCE EDUCATION

UNIVERSITY OF BRITISH COLUMBIA

PLEASE ANSWER THE FOLLOWING QUESTIONS BY PLACING A CHECK IN THE APPROPRIATE BOX. ADDITIONAL COMMENTS MAY BE MADE ON THE BACK OF EACH PAGE.

1) What grade level did you bring to the workshop?

Grade 5 ☐ Grade 8 ☐ Grade 11 ☐

2) Which of these describes your class? Tick one box or please specify.

Science Class ☐ Art Class ☐

Other, please specify. ______________________________

3) How many students were in the class which attended the workshop?

Under 10 ☐ 11-15 ☐ 16-20 ☐ 21-25 ☐ 26-30 ☐ Over 30 ☐

4) How many field trips away from your school will you take with this class during the school year 1980-81?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ more than 5 ☐

5) What was the purpose of this visit?

Review work studied in class ☐

Provide enrichment ☐

Introduce a new unit ☐

Teach core subject matter ☐

Other, please specify. ______________________________

6) Was the time allocated for your students' visit sufficient?

Yes ☐ No ☐ Undecided ☐

Please comment.

7) Did this workshop meet the original expectations you had for yourself?

Yes ☐ No ☐ Undecided ☐

Please comment.

8) Did this workshop meet the original expectations you had for your students?

Yes ☐ No ☐ Undecided ☐

Please comment.

9) In what ways did this workshop experience differ from what you could provide in your classroom?

10) How would you rate the overall value of this workshop?

Excellent ☐ Good ☐ Fair ☐ Poor ☐

11) Were the exhibits appropriate for the age level of your class?

Yes ☐ No ☐ Undecided ☐

Please give examples.

12) Please use the following adjective pairs to describe the "Light and Illusion" workshop. Each of the following adjective pairs helps to define the exhibition or the relationship among the various exhibits. Put a check-mark somewhere along the line (example: ___:✓:___) to indicate what you think is an appropriate description.

varied	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	redundant
simple	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	complex
novel	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	familiar
small scale	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	large scale
similar	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	contrasting
dense	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	sparse
intermittent	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	continuous
usual	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	surprising
heterogeneous	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	homogeneous
uncrowded	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	crowded
asymmetrical	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	symmetrical
immediate	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	distant
common	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	rare
patterned	___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___	random

13) Have you noticed any positive effects on your students as a result of your visit to the exhibition?

Yes ☐ No ☐ Undecided ☐

Please indicate those positive effects.

14) Have you noticed any negative effects on your students as a result of your visit to the exhibition?

Yes ☐ No ☐ Undecided ☐

Please indicate those negative effects.

15) Do you think that the printed guide material provided was appropriate for your class?

Yes ☐ No ☐ Undecided ☐

Please comment.

16) Do you think that the assistance provided by the explainers was appropriate for your class?

Yes ☐ No ☐ Undecided ☐

Please Comment.

17) Did you involve your students in any followup activities in the classroom after the workshop?

Yes ☐ No ☐

Please give examples.

18) Did the followup activities specifically suggested in the guidebook help you extend the workshop experiences in the classroom?

Yes ☐ No ☐ Undecided ☐

Please give examples.

19) If it were possible, would you bring the same class back to this workshop?

Yes ☐ No ☐ Undecided ☐

Please comment:

20) If it were possible, would you bring another class to this workshop?

Yes ☐ No ☐ Undecided ☐

Please comment.

21) How best could your students be prepared for a workshop such as this?

22) Would you like your class to attend workshops of this type on other topics?

Yes ☐ No ☐ Undecided ☐

Please comment.

APPENDIX B

Treatment of Data Obtained from Item 12 of the Questionnaire

Teachers were requested to score the workshop experience on a semantic differential scale (item 12) designed to measure the ability of a particular experience to stimulate or arouse interest in an observer or participant (Mehrabian, 1974). With respect to these affective responses, Pierotti (1973) has found that visitors to museums are unable to directly verbalize feelings and ideas about their experience. So in order to elicit this information it is necessary to use standardized psychological measures such as the semantic differential. Each point of the semantic differential scale (item 12, questionnaire) was given a value from one to nine. Scales marked (-) were given a negative score; scales marked (+) were given a positive score; the (+) and (-) markings were omitted from questionnaires used in the survey. The total semantic differential score for each respondent was calculated by subtracting the sum of the negative scores from the sum of the positive scores. The mean score for intermediate teachers (n=43) and the mean score for secondary teachers (n=28) were then calculated. The scores of the primary teacher group (n=5) were omitted from this sample due to the small number of primary teachers participating in this survey. Eighteen teachers who responded to the questionnaire did not complete item 12.

Semantic Differential Scores for Individual Teachers
by Grade Level, N=76

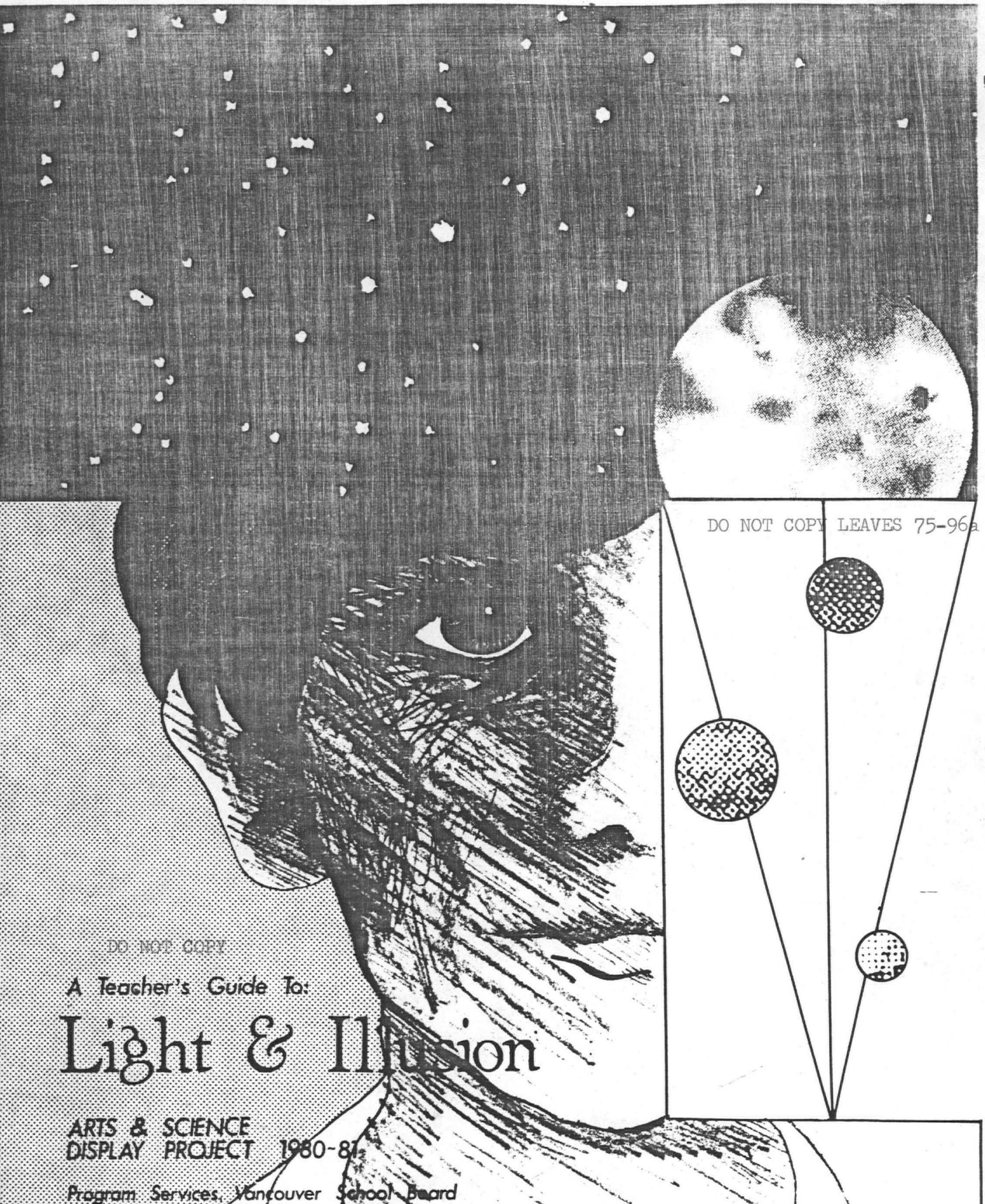
Primary Subgroup (Gr. 1-3) $m_p = 5$	Intermediate Subgroup (Gr. 4-7) $m_i = 43$		Secondary Subgroup (Gr. 8-12) $n_s = 28$	
+ 8	+ 13	+ 6	+ 9	+ 9
+ 11	+ 14	+ 16	+ 8	+ 7
+ 8	+ 9	+ 11	+ 11	+ 15
+ 7	+ 28	+ 14	+ 3	+ 6
- 1	+ 2	+ 1	+ 7	+ 10
	+ 22	+ 5	+ 5	+ 9
	+ 16	+ 21	+ 8	+ 9
	+ 11	+ 8	+ 9	+ 5
	+ 26	+ 13	+ 19	+ 5
	+ 28	+ 7	+ 30	+ 7
	+ 8	+ 9	+ 12	+ 10
	+ 12	+ 8	+ 24	+ 10
	+ 21	+ 4	+ 19	+ 11
	+ 23	+ 5		+ 5
	+ 16	+ 10		
	+ 12	+ 5		
	+ 17	+ 12		
	+ 16	+ 20		
	+ 9	+ 9		
	+ 6	+ 15		
	+ 16	+ 13		
	+ 9	- 3		
		- 2		
Total subgroup score 33	524		278	

$$\text{subgroup mean} = \frac{\text{total subgroup score}}{n_x}$$

$m_p = \frac{33}{5} = 6.6$ $\qquad m_i = \frac{524}{43} = 12.19$ $\qquad m_s = \frac{278}{28} = 9.93$

$$\text{mean score for all teachers} = \frac{\text{total scores}}{N} = \frac{835}{76} = 9.57$$

Note: nil response for item 12 = 18 (19%)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LIGHT AND ILLUSION

Introduction

Art and Science both provide us with tools that extend the boundaries of our experience, helping us to perceive, understand and manipulate the world we live in. Optical devices such as the microscope and the telescope become an extension of our eyes. The periscope enables us to see around corners. Lasers, invented and used by scientists, are also used by artists to produce three-dimensional images called holograms. Illusions are used by scientists to illustrate limitations of observation and by artists to create dramatic effects.

In "Light and Illusion" an attempt has been made to provide teachers and students with an interdisciplinary experience. Art and science are not really distinct but merely reflections of how humans with different philosophies perceive the world.

Cary Chien	-	David Thompson
Neil Prinsen	-	Killarney
Betty Wellburn	-	VSB Art Coordinator
John Worobec	-	VSB Consultant
John Zappavigna	-	Mount Pleasant

A. LIGHT AND COLOUR

The science of colour perception is still in its infancy. How the eye collects colour information is now known, but how the brain processes it is a matter of controversy. Much of the practical knowledge in this field has come from artists, to whom the knowledge is of supreme importance.

General Goal:

The student will develop some understanding of the nature and the properties of light and colour.

Notes on Colour

COLOUR: The study of colour falls within the fields of physics, physiology and psychology.

Physics studies the radiant energy of light which stimulates vision and in general the objective physical characteristics of the stimulus situation. A special branch is the study of pigments and dyes in relation to their colour producing properties.

Physiology studies the electrochemical activity in the nerves and in general the processes which take place in the eye and brain when a stimulus situation results in an experience of colour.

Psychology studies the awareness of colour as an element of visual experience. Different concepts of colour are based in these fields and difficulties of the subject have often been complicated by failure to keep them distinct.

All three have a bearing on the problems of colour in relation to art.

a. For the purposes of teaching young people about colour we could point out such psychological approaches as:

   1. Warm and cool colours.
   2. Advancing and receding colours.
   3. Symbolic use of colour.
   4. Expressive colours.

b. In the physical approach, lessons or exercises could be used that deal with:

   1. The prism. (White light and the spectrum).
   2. The Primary, Secondary, Tertiary and Complementary colours.
   3. Mixing of colours.
   4. Pointillists and Mosaicists.
   5. Texture or diffusion of light e.g. (mat, translucent, glossy, transparent colours).

The psychophysical approach could include:

Organs of vision, brain processes, optical pathways, colour-vision theories; e.g. contrast of colours in relation to other colours, hue, saturation, brightness, juxtaposition, spatial factors, local or natural colour.

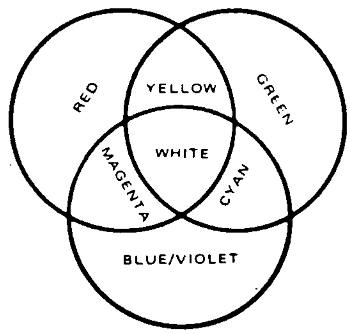
Included in this unit are some ideas for lessons from the aforementioned approaches. These are simplified versions which can be adapted for different age levels.

Colour is an extremely important Art Element, and if possible, the theories presented should be reviewed in each year of the child's art education.

A. 1. Colour Wall

Red, blue and green lights project coloured shadows of the viewer against a white wall.

Most of our experience of mixing colours comes from mixing paint or food colouring. Pigments assume their colours because of absorption; they subtract from the white light striking them and reflect only certain colours. When two pigments are mixed, two subtractions take place. Less light and fewer colours are reflected. The primary colours for paint are red, blue and yellow.



Green can be produced by adding blue pigments to yellow pigments. This combination will subtract all colours from white light except green which is reflected.

The mixing of pigments or dyes is a complicated matter and this explanation is simplified.

Colours can also be made by mixing light, whose primary colours are red, blue and green. Our eyes are sensitive to these three basic colours; when we see other colours we are responding to a mixture of these. Mixing light is different from mixing paint. In this case, the contributions add equal parts of red plus green to make yellow. This kind of colour mixing takes place on the screen of a colour television, which when illuminated is a mosaic of dots or stripes in the primary colours of red, blue and green.

Mixing Light

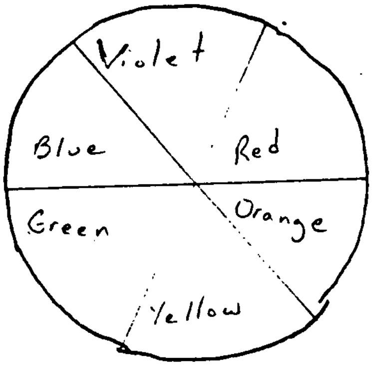
Learning Outcome: The student may understand the additive principle of mixing colour.

For follow-up:

1. <u>An Experiment with rainbow colours.</u>

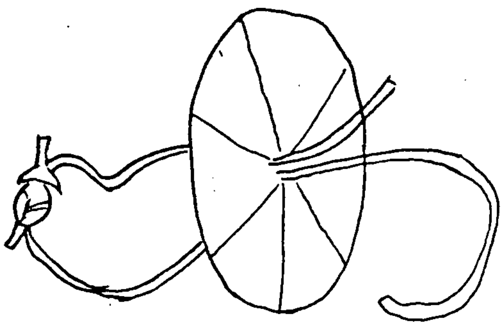
Here is an experiment which shows 'white' light. You will see how six different colours blend into one colour when they are moving at a great speed. You will need: a circle of white cardboard about the size of a small saucer, two pieces of string about one metre long, bright crayons in the six colours of the rainbow and a sharp pencil.

Step 1:



Draw six lines on one side of the circle so that you have six equal sections. Colour each section with a different colour crayon.

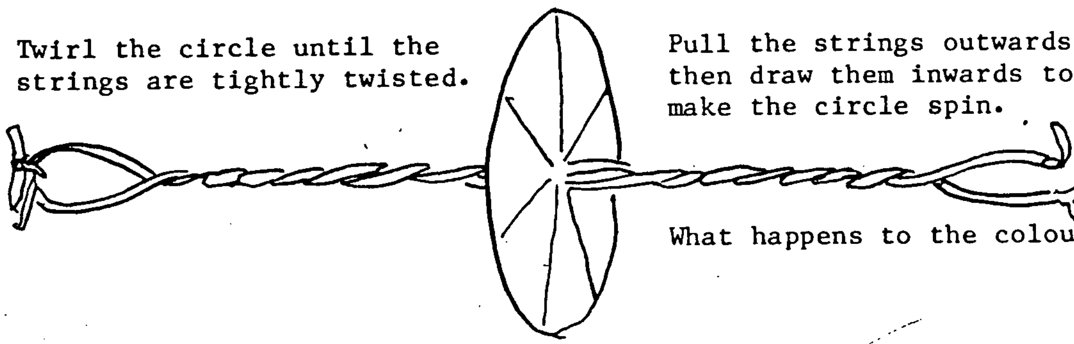
Step 2:



Carefully prick two holes in the centre of the circle with a pencil. Thread a different string through each hole. Knot the two strings together at the ends.

Step 3:

Twirl the circle until the strings are tightly twisted.



Pull the strings outwards, then draw them inwards to make the circle spin.

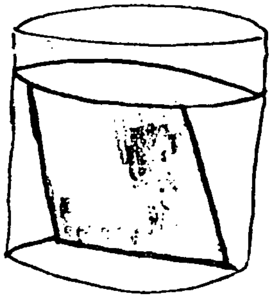
What happens to the colours?

2. Colours of Objects in Coloured Light.

You will need: flashlight; piece of green, red, or blue cellophane; tape; variety of colourful things, such as books, marbles, and coloured paper.

1. Tape the cellophane over the end of the flashlight as pictured.
2. In a dark room, shine the flashlight on each object.
3. Have your partner write down what colours he/she sees when each object is illuminated.
4. Then have the people write down what colours they think the objects would be in white light.
5. Take the cellophane off the flashlight.
6. Shine the flashlight on the objects.

Object	Colour Under Green Light	Colour Under Red Light	Colour Under Blue Light	Colour Under White Light



3. Make Your Own Prism

You will need: small, flat mirror; glass of water; white piece of paper.

1. Place the mirror in the glass of water as pictured.
2. Put the glass in the sunlight so that the mirror faces the sun.
3. Put the paper at a slant in front of the glass.
4. Move the paper until you can see the colours clearly.

1. What colours do you see?

____

____

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2. Why can you see them?

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Tap the glass lightly.

3. What happens to the colours? Why?

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4. Use prisms:

   a) to break white light into its colours and

   b) to make white light from the spectrum created by the first prism.

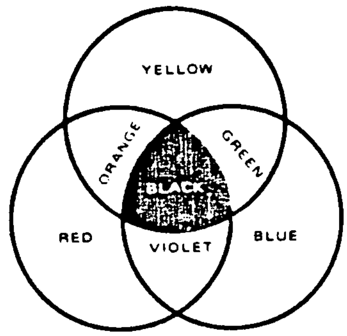
5. Make your own colour wall using various means: e.g. flashlights and large onion skin paper.

6. Discuss the additive principal of mixing colour light.

7. Try to explain how the colour is mixed on the screen of a colour television.

A.2 Mixing Primary Pigments

The three primary pigment colours are red, yellow and blue. The mixtures of any two of these hues forms a secondary colour. The secondary colours are orange, green and violet.



Mixing Pigments

On the colour wheel, when a primary colour (e.g. red) is mixed with its adjacent secondary colour (e.g. orange), a tertiary colour is formed (e.g. red-orange).

Colour can have hue, saturation and lightness. Hue is the degree of colour, it is really another word for colour. Saturation is the amount of colour, i.e. its intensity, or brightness or dullness. Lightness or darkness of colour is called its value; i.e. tints and shades.

COLOUR RELATIONSHIPS -- SUBTRACTIVE

Subtractive: Process of taking away: of PIGMENT COLOUR: where combination of colour produces black.

The Subtractive PRIMARY COLOURS are RED/YELLOW/BLUE.

RED	YELLOW	BLUE

The PRIMARY COLOURS CAN NOT BE MIXED.

Other colours can be mixed from the primary colours i.e. the SECONDARY COLOURS.

RED	+	YELLOW	=	ORANGE
YELLOW	+	BLUE	=	GREEN
RED	+	BLUE	=	VIOLET

Learning Outcomes:

The student may understand the subtractive principle of mixing colour pigments.

The student should realize that there is a difference between additive and subtractive colour mixing principles.

For Follow-up:

1. Mixing Colour Pigments

Colours can be mixed to create specific new colours.

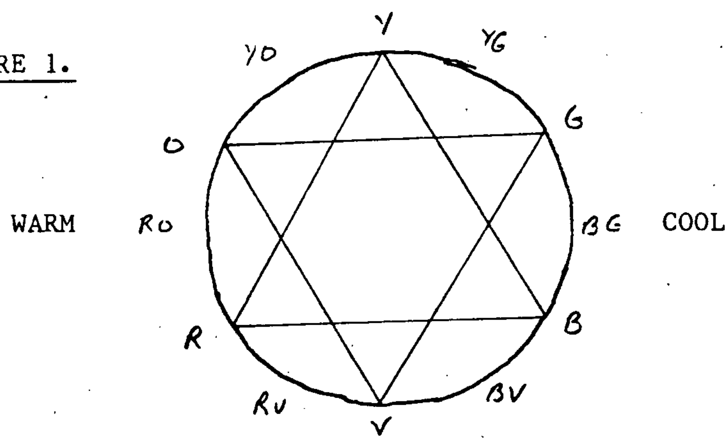
Suggested art activities:

- This lesson is not meant to be simply mixing of colours to get other colours. It should be done carefully and precisely. It is here the mixing of the primary colours - red, yellow, blue - are introduced, e.g.

  - "What colour will we get when we mix yellow and red?"
  - "What colour will we get when we mix yellow and blue?"
  - "What colour will we get when we mixed blue and red?"

- Display a colour chart of the primary and secondary colours (colour wheel). Have it contain a triangle forming the primary colours and an inverted triangle forming the secondary colours. Note that the "warmer" tones are on one side of the wheel, i.e. red, yellow, and the "cooler" tones are on the other side. See figure 1.

FIGURE 1.



- Have an overhead projector, transparencies and overlays that show the mixture of primary colours producing secondary colours. Three petri dishes and liquid food colouring with eye droppers can be used.

- Make a math game with equations for the children to solve. Y = Yellow, B = Blue, R = Red, G = Green, O = Orange, P = Purple. Put these equations on the chalkboard and have children solve them:

Y + R = ?
O - R = ?
B + Y = ?
Y + ? = O

- Have class paint a picture using only the primary colours plus black and white. The circus is a particularly good theme for this.

- Use oil pastels - encourage the children to draw strands of the primary colours, purposely overlapping them, so that the resulting secondary colour appears between the colours.

- Prints that could be used for this concept:

  "Mlle. Viotte" - by Redon
  "Women in a Garden" - by Monet
  "Rebus" - by Robert Rauschenberg
  "Madam Cezanne in a Red Chair" and "The Little Bridge" - by Paul Cezanne

- Filmstrip: "The Yellow Balloon".

- Books: "Hailstones and Halibut Bones" and "The Adventures of Three Colours".

2. <u>Suggested art activities:</u>

   - Discuss the importance of colour in everything we do - in nature, in food, in clothing, in homes, even in the way we feel.

   - The concept of secondary and tertiary colours should be introduced - a full colour wheel such as "Grumbacher's Colour Compass" could be displayed.

   - Introduce the science concept: All colours <u>in light</u> mixed together make white and the absence of colour makes black. Use a prism and a light source to demonstrate colour formation. <u>Remember:</u> Primary colours in light differ from primary colours <u>in pigment</u>, (paints or dyes).

   - Do vocabulary exercises using all colours, i.e. yellow, amber, topaz, etc.

   - Have class construct their own colour wheel on a bulletin board. Use colours that are as pure as possible. Have children place the correct colour in its area of the colour wheel.

   - Use prints to study this concept.

- Suggested art reproductions.
  "Apples and Oranges" - by Cezanne
  "Composition 1963" - by Miro
  "Tamaracks" - by Tom Thompson
  "The Elements" - by J.E.H. Mac Donald
  "Beamsville" - Frank Johnson
  "Entrance to Halifax Harbour" - by A.Y. Jackson

3. Examine a colour photograph in a magazine with a magnifying glass to see the individual coloured dots.

4. Study "Animal Camouflage" by reading; making notes and models.

5. Design an experiment to test the comparative visibility of various car colours.

A.3 <u>Liquid Crystals</u>

The participant creates coloured patterns by touching liquid crystal sheets.

Most people are familiar with liquid crystals in the form of mood rings, temperature strips and other commercial products. Thousands of organic molecules have a liquid crystal phase, which is intermediate between solid crystals and ordinary liquids. Liquid crystal molecules do not have fixed positions, so the material can flow like a liquid. But the forces between the molecules are sufficient to maintain certain alignments between them. Some types of liquid crystal molecules all point in one direction; the molecules of other kinds group themselves in layers. In one type, called cholesteric (after cholesterol) rod-like molecules are arranged in layers, with the rods in each layer pointing in a slightly different direction, like an array of spiral staircases.

Because the forces between liquid crystal molecules are weak, the orientations are easily modified by heat, pressure, and electric and magnetic fields, changing the colour and other properties of the liquid crystal. Liquid crystals are, therefore, ideal candidates for sensors and are the bases of such items as the fever headband on sale in drug stores. They are also used for displays in pocket calculators, because it takes very little energy to maintain the colour change, and so batteries last longer.

Learning outcome:

The student should observe the colour of liquid crystals change with temperature change.

For follow-up:

1. Collect pictures and objects which demonstrate the use of liquid crystals. Set-up a display in your classroom.
2. Find the meaning of the following words: molecule, crystal, property and sensor.

A.4 Lighting

Three types of street lamps (sodium vapour, mercury vapour and incandescent) produce very different colour effects.

In today's energy-conscious world, it seems sensible to use the most efficient lighting system available to light our cities. Sodium lamps produce considerably more light per kilowatt than mercury lamps, which in turn are more efficient than incandescent lamps, which give off and waste a lot of heat radiation. But there are also aesthetic considerations. Incandescent lamps produce light of all wavelengths, and their light is warm and natural. At the other extreme, low-pressure sodium lamps emit a pure yellow colour. Coloured surfaces that happen to absorb this wavelength look black. High pressure sodium lamps emit some red light. Mercury lamps emit mainly yellow-green, green, and blue light.

Learning Outcome:

The student should observe the colour of various objects that will be affected by the source of the light.

For Follow-up:

1. Activity "Street Lights"

Lightness and darkness at various levels may influence how colours are seen.

Suggested art activities:

- Display art prints and photographs showing varying degrees of light and darkness. If possible have two pictures of the same scene - one at night and one in daylight.
- Discuss sources of light, e.g. sun, moon, candle, neon, street lights, fluorescent lights and their affect on colours.
- Use several coloured scarves - some opaque and some transparent - to drape over objects to show the effect of filtering light.
- Exhibit prints showing different times of day and of night.
- Read "Hide and Seek Fog" by Tressett.
- Discuss the affects of fog on colours in comparison with clear, sunny day.

- Create a drawing, a painting, or a collage suggesting a particular time of day or objects seen in a specific kind of dim light.

- Suggested prints:

  "Rockets and Blue Lights" - by Turner
  "Dancing Class" - by Degas
  "Boats at Argenteuil" - by Monet

LEARNING OUTCOME: Pupils will demonstrate their awareness of the concept by their interest and participation in discussion (with special focus on the accuracy of his verbal responses). Vocabulary: clear, sunny, misty, foggy, dim, light, transparent, opaque.

2. The colours of some objects differ in different kinds of white light.

You will need: things with a variety of colours, such as clothes and books; incandescent lamp; fluorscent lamp; sunlight.

Look at each object under each kind of light.

1. Is each colour different under each kind of white light? If so, why?

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2. How is each colour different?

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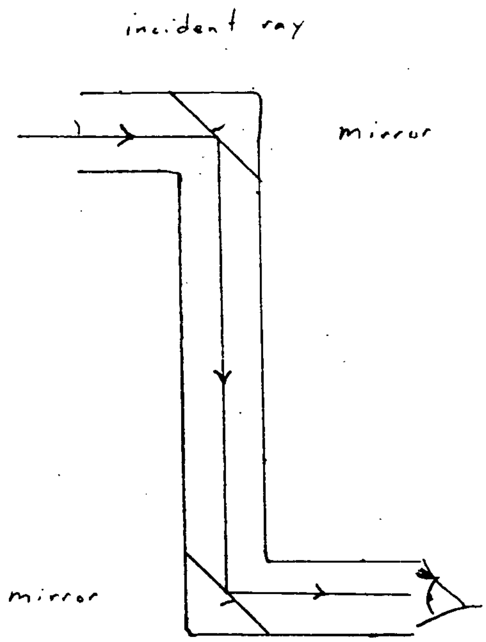
B. LIGHT - REFLECTION AND REFRACTION

Things are not always what and where they appear to be. You may have great difficulty finding your way out of a maze of mirrors at a carnival. A coin dropped in a swimming pool may not be located exactly where you think it is. A puddle may appear to exist at some distance down a perfectly dry highway on a hot summer day. These are examples of reflection and refraction. There are many other examples of reflection and refraction in the exhibits in this section.

General Goal: the student will experience the nature of reflective and refractive properties of light.

B.1 Periscope

A large periscope for over-the-shoulder viewing.



This periscope has two flat mirrors angled at 45 degrees to direct the light back into the viewer's eyes. It is different from the toy periscope you may have seen, because it also has a translucent screen mounted between the mirrors, and a lens that focuses an image on the screen. This makes the instrument a periscopic "camera". Focusing is accomplished by turning the submarine-style handlegrips. Visitors should try to understand why the screen must be moved up and down to focus on a nearer object.

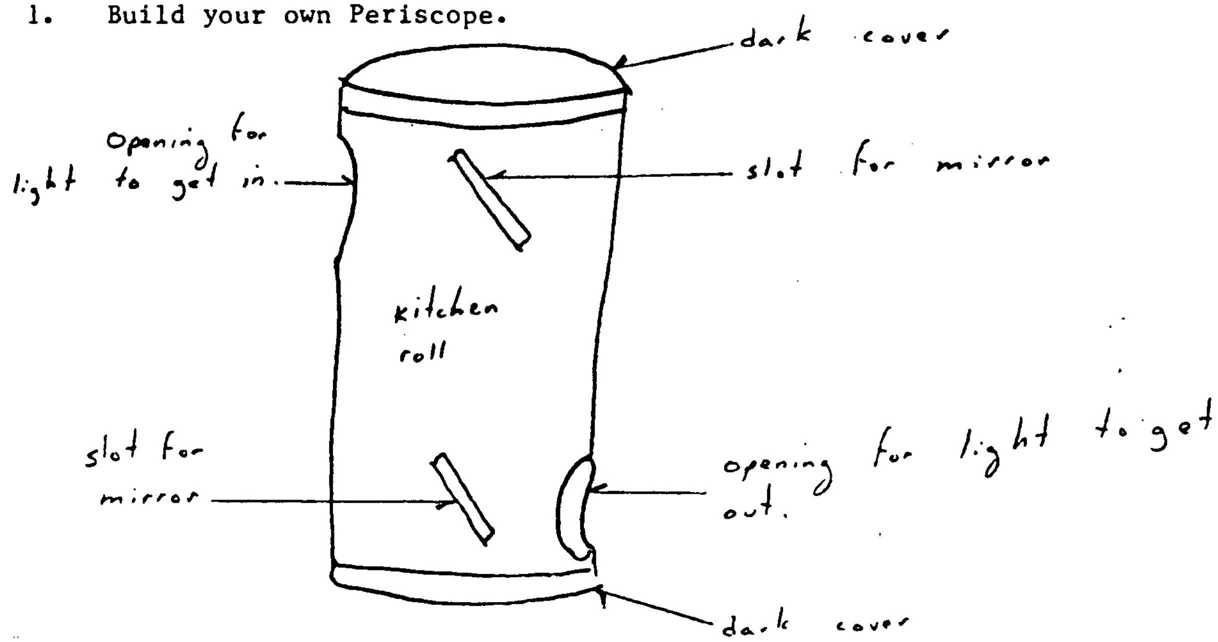
Learning Outcomes:

- the student should understand that the periscope extends their vision by the use of relection and refraction of light.

- the student should experience focusing an image on a screen.

For Follow-up:

1. Build your own Periscope.



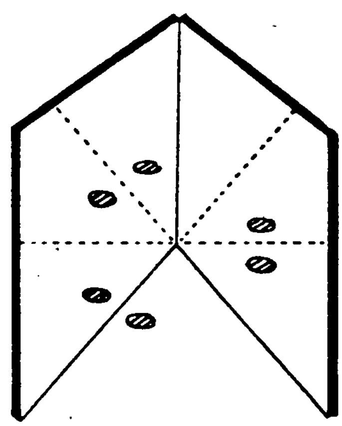
2. Use your periscope to extend your vision.
   e.g. look around corners and over the top of counters.

B.2 Walk-in Kaleidoscope

A walk-in kaleidoscope, with large mirrors arranged in an equilateral triangle, reflects an infinity of images.

The effect is a little different from that seen in a toy kaleidoscope, which has a pair of angled mirrors that produce a symmetric six-sided pattern. Standing inside the kaleidoscope, the visitor is surrounded by duplicates of himself standing inside triangular boxes and facing in different directions (see fig.).

WALK-IN KALEIDOSCOPE

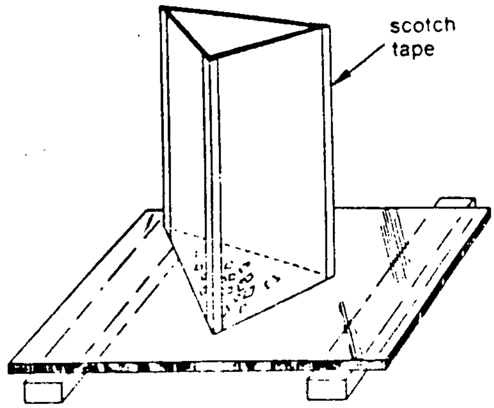


Learning Outcome:

The student should experience and/or understand the formation of multiple images through the reflection of light in three mirrors.

For follow-up:

1. Make a Kaleidoscope.



Beautiful multiple images can be obtained from a kaleidoscope. To make one, tape together three long rectanglular mirrors, all of the same size, to form a triangle with the reflecting surfaces on the inside. Metal camp mirrors, cut with tin shears or a hacksaw, can also be used. Sprinkle tiny pieces of coloured paper on a pane of glass set on two blocks of wood. Set the kaleidoscope over the paper bits on the glass. Six-sided patterns will be seen. Tap the glass or turn the kaleidoscope to change the pattern shape and colour combinations. Repeat the experiment, using coloured beads, bits of coloured glass, coloured yarn, or tiny pieces of coloured ribbon.

2. Try to create other arrangements of mirrors that will result in multiple images.

B.3 Star Tracing

The visitor tries to trace the outline of a star viewed in a mirror.

The game tests adaptation to contradictory sense inputs. The visual inputs are reversed in space and conflict in a most frustrating way with the sensations communicated by muscles in the hand and arm. The display reminds us that there are more than the five traditional senses of sight, hearing, taste, smell and touch. Others include the sense of position and movement used here.

Learning Outcome: The student experiences how easily the brain can be fooled by reflected light.

For follow-up:

1. Images in mirrors are reversed.
   To illustrate this write your name on a piece of paper and hold the paper up to a mirror. Is the image reversed or is your brain confused? Discuss this with your classmates.

2. Stand face to face with a classmate. One student should play the part of the mirror, the other should move their hands or feet.

3. Make a drawing or a painting which includes a reflection.

B.4 Tilings

Coloured tiles and a mirrored playing surface.

The symmetry of tiling patterns and the pleasure of seeing different shapes fitted neatly together have stimulated artists and architects to include tilings in their designs. Mathematicians use tiling patterns to explore geometric puzzles.

Participants in this exhibit can play many different games with the tiles, or simply try to create attractive patterns. The tiles can be combined to form pleasing geometric shapes, to examine principles of geometry or to depict animals, plants and even faces.

Learning Outcome:

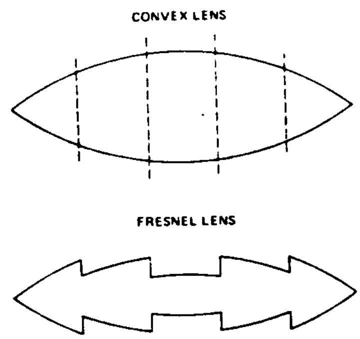
The student should create a symmetrical pattern using tiles and mirrors.

For Follow-up:

1. Create a similar light table in your own classroom using an overhead projector and two mirrors.

B.5 Fresnel Lens

In this exhibit Fresnel lenses are mounted for see-through viewing, as are samples of headlight lenses and other applications.



FRESNEL LENSES

The curved surface of any lens does the work, because that is where the light is bent from its original path. A Fresnel (pronounced Fren-ell) lens is a clever way of keeping the surfaces and getting rid of most of the inside. In the Fresnel construction, the lens is sliced into concentric rings and each ring is collapsed to be as thin as feasible (see fig.) The resulting lens works well for rays travelling parallel to the axis of the lens, but, of course, rays coming in at an angle will "see" the cut surfaces, producing a degraded image.

Fresnel lenses are used where lightness, space and cost are important considerations. Typical applications are automobile headlight lenses and the large aperture lens in overhead projectors or spotlights.

Learning Outcome: the student should understand how the thickness and weight of a lens can be reduced by the Fresnel Principle.

B.6 You And Me

Two people sit on opposite sides of a one-way mirror. They adjust the light level so both see a composit face: half theirs and half their partner's.

That is what people call a one-way mirror -- except that it works both ways. The mirror is silvered so half the light that strikes it passes through and half is reflected. If the light level is bright on one side the reflection swamps the relatively weak transmitted image. On the dim side the reverse occurs; the bright side is seen clearly and the reflection is not noticeable. (A spy suspecting he is being observed through such a one-way mirror could try to spot his observers by carefully darkening the room before looking into the mirror.) When the light levels are equal, the reflected and transmitted images are equal in intensity and the viewer has the disconcerting sense of his own feature merging with someone else's.

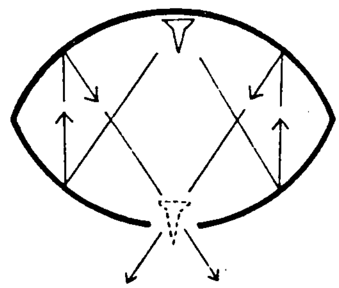
Learning outcome:

The student should understand that if the light level is bright on one side and dim on the other, then the student on the bright side will see his own reflection and the student on the dim side will see the other person through the mirror.

B.7 Real Image

A quarter seems to be there for the taking, but it's just a convincing illusion.

A pair of concave mirrors -- one with a hole in it -- form the image of an actual quarter. They act like a lens, sending the light rays from each part of the quarter to a matching spot in the circular opening. When all the rays are seen together, it is as if there were a second quarter hanging in the air. This is a striking example of so-called real image. The actual quarter, located directly beneath the image, can be seen only with effort.


REAL IMAGE

Learning outcome:

The student should understand the difference between a real image and a real object by direct experience.

B.8 Anamorphic Art

Another kind of distorted picture, which can be viewed properly only in a cylindrical mirror.

These pictures can only be viewed with a special mirror. The mirror converts a co-ordinate transformation painstakingly applied by the artist, into a recognizable image.

This display is an example of anamorphic (Greek ana: again and morphe: form) art, a style that was popular in Europe and the Orient in the 17th and 18th centuries. Sometimes the style was used to hide messages of political protest, but mostly the pictures were made simply for the wonder of the effect.

Learning outcome:

The student should experience how the special mirror affects a co-ordinate transformation painstakingly applied by an artist.

For follow-up:

Students could try to produce some simple anamorphic art. A mirror shaped like a cone could be used instead of a cylindrical mirror.

B.9 Curved Mirrors

Curved mirrors produce effects determined by the direction in which they curve. A concave mirror forms a larger image of an object, while a convex mirror forms a smaller image of an object. The effect is opposite to B.8 Anamorphic Art.

Learning outcome:

Students should understand why curved mirrors distorts their images.

For follow-up:

1. A display of curved mirrors could be set up in the classroom. They could include a metal coffee pot, shaving mirror, rear-view mirror and others.

2. Look up the words convex and concave.

B.10 Transparent, Translucent and Opaque

When artists use paints for painting or glazes for ceramics, they pay special attention to transparent, translucent and opaque techniques and materials.

Learning outcome:

The student should understand that artists use the principles of transparent, translucent and opaque light in their work.

C. LIGHT-IMAGES

Images can be real or virtual. An image is real when light rays actually do meet to reproduce the object, while an image is virtual when light rays do not pass through it.

Interesting images are produced with laser light and with polarized light. The images viewed through a zoetrope give the illusion of movement.

General Goal:

The student will understand that painting, photography and other visual arts are concerned with the manipulation of light.

C.1 Lasers

A low-power laser reflected by two spinning mirrors traces figures on a screen.

Laser light is exceptional for two reasons: its wave-length is very precisely defined (all the waves are vibrating at the same rate), and the individual waves in a burst of laser light are tightly in phase with each other (when one wave goes up, they all go up). This is a consequence of how the light is produced. The lasing atoms are "pumped" into an excited state by a burst of ordinary light. Then they return to their original state, emitting light as they go. They do so by "stimulated emission", which means that each atom is triggered to emit light by the light of another atom. The chain reaction is like a row of falling dominoes. Each atom "falls" the same distance, so all the light has the same wavelength. Because each wave is triggered by another, all the waves are in phase. Partially-silvered mirrors at either end of the laser chamber increase the effect by directing the light back and forth while letting a little of it escape as the laser beam. "Laser" is an acronym standing for Light Amplification by Stimulated Emission of Radiation.

Learning Outcome:

- The student should experience an enjoyable function of the laser.
- The more advanced student should understand in general terms how a laser functions.

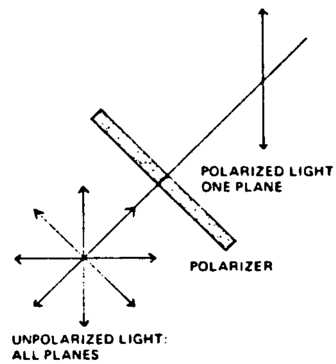
For follow-up:

Students could do library research involving the use of lasers. A number of articles have recently appeared in science magazines.

C.2 Polaviewer

Experiments with polarized light.

Light waves vibrate sideways. To be more precise, light propagates as electromagnetic waves oscillating in planes which are at right angles to the direction of propagation. This still makes many different planes of oscillation possible (see fig.). A beam of light pointed at the ceiling has some waves vibrating north to south, some east to west, and so on.



POLAVIEWER

Polarized light can be generated by a material that transmits only light vibrating in one particular plane. The surface of the light table in the exhibit is covered with such a polarizing axes parallel to the axis of the film on the table, they appear transparent. When they are rotated so their axis are at right angles to the table's, they appear black, because all the remaining light is being filtered out.

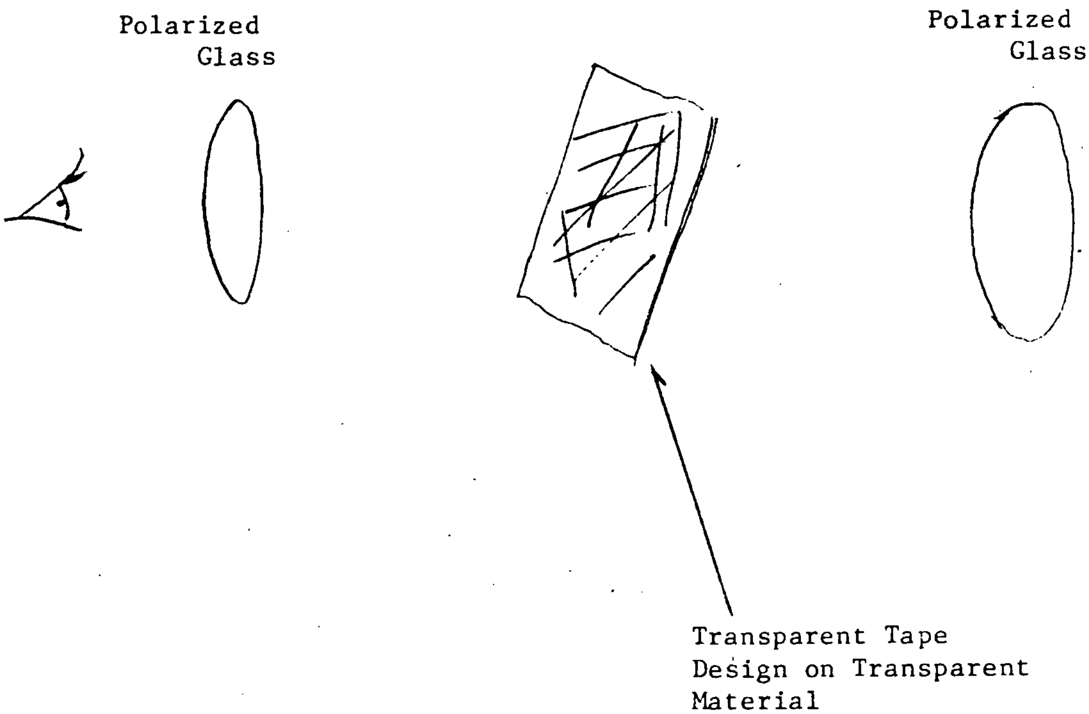
Certain kinds of materials, including plastics under stress, change the polarization of light passing through them. If a clothespeg is viewed between crossed polaroids, stress lines and colour patterns appear when it is opened.

Learning Outcome:

The student should understand that polarized light can be generated by a material that transmits only light vibrating on one particular plane.

For follow-up:

1. Polarized Light Art



- Using transparent tape make a design using different layers on a piece of transparent material.
- Put this design over a polarized glass and look through your other polarized glass at your design.
- Why do the colours appear and why do the colours change?

C.3 HOLOGRAMS

Four holograms, illustrating their three-dimensional character and their ability to reproduce various optical effects:

- A scene including a moire screen, which superimposes contour lines on a model.

- A double exposure of some ping pong balls, with and without a weight on top. The interference causes strain contours to stand out.

- A stop-action moving hologram (see C.4.).

- A hologram reflected in a mirror.

A typical hologram image is made by shining a light on a film covered with a fine pattern of lines, smudges and blobs. The seemingly random pattern is really a very clever code that records every detail of the original scene. It is made by splitting a beam of laser light and reflecting half of it off the scene to be photographed. The reflected beam and the undisturbed beam are then brought together, and the resulting intensity distribution is recorded on the film. When a hologram is illuminated with another laser beam (or even, in some cases, with a beam of white light), it scatters the beam to produce images of the original scene.

The success of the hologram depends on the precise interference between the scattered beam and the undisturbed reference beam. Laser light is used because it is coherent, and great care is taken in setting up the laser photo to avoid vibration or movement.

The hologram is not a simple two-dimensional projection. It is an approximate reconstruction of the actual wave-front coming from the scene, so it is three-dimensional and the viewer can look behind objects in the scene. A curious feature of the hologram recording is that any piece cut out of the hologram can reproduce the entire scene.

Learning Outcome:

The student should experience the hologram noting the three-dimensional real image and the results of moving around the image.

C.4 Moving Hologram

Holograms that move as the viewer changes position.

These holograms are similar to an ordinary motion picture. A series of holograms recording the action is printed on a curved strip of film. As the viewing angle changes, first one scene and then another appears. Each image is stationary as long as it is visible, so no shutters are necessary to block out the view while the frames are changing (as is the case with a conventional movie projector).

Learning Outcome:

The student should understand that the image in this moving hologram actually moves as the viewer changes position.

AN INTRODUCTION TO HOLOGRAPHY
(EXHIBIT REFERENCE NUMBER: A.7, 8, 9.)

Written by
Rick Gibson,
local holographer for the Arts and
Sciences Centre Preview Exhibition
February 15 - May 19, 1980

The following description is only a general outline of holographic theory, with certain points being simplified for the sake of brevity. For the reader who wishes a more comprehensive description, there is a reading list at the end of this article.

WHAT IS LIGHT?

Generally speaking, light is energy. One theory, which explains some of the behaviour of light, is called "The Wave Theory" because it compares light with waves. A wave pattern can be symbolized as follows:

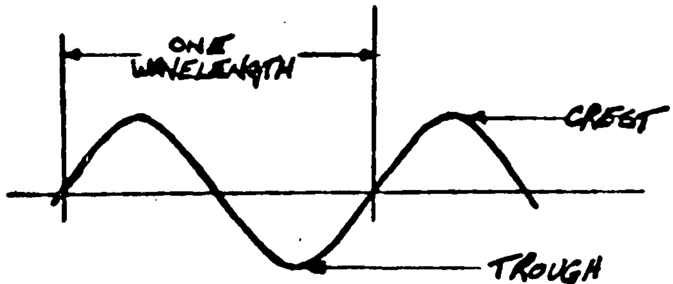


FIG. #1

The wave theory is used to describe the differences between various colours. Blue light is said to have a shorter wavelength than green light which has a shorter wavelength than red light.

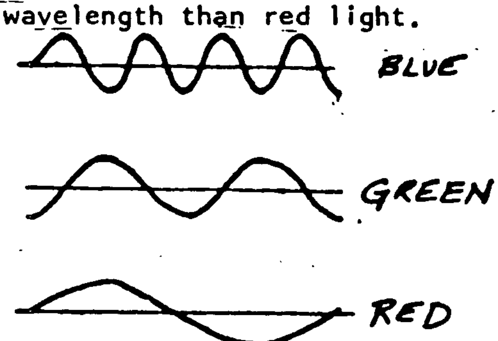


FIG. #2

The white light coming from the sun or from a light bulb contains a mixture of blue, green and red light (known as the visible spectrum) and when white light is passed through a prism it is separated into its various wavelengths.

LIGHT RAYS

If you were to study a shadow that was cast by an object that was illuminated by the sun, you would be studying one example of how light travels in straight lines or rays.

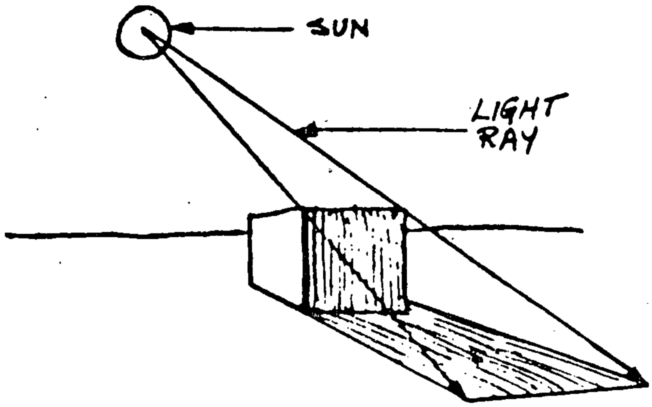


FIG. #3

Light, however, can be bent around corners. One method is to reflect the light ray by using a mirror. Objects also reflect light.

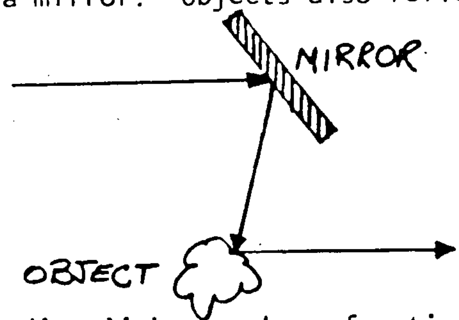


FIG. #4

Two other methods of bending light are by refraction and diffraction. A light ray can be refracted by allowing it to pass through a clear substance such as glass or water. Light rays can be diffracted by passing them through tiny holes (smaller than the holes in nylon stockings).

REFRACTION

As a ray of monochromatic light (only one color) enters and passes through a piece of glass it will be bent as in Fig. #5. If the piece of glass is cut and shaped into a prism, it will bend a light ray as in Fig. #6.

FIG. #5

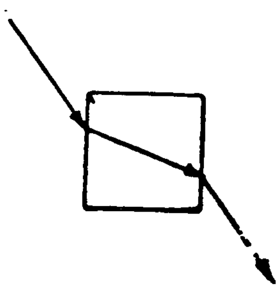
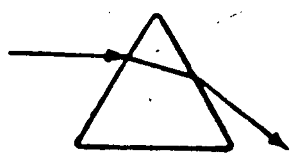
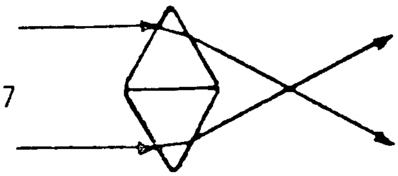


FIG. #6



When two prisms are mounted on top of each other as in Fig. #7, the light rays are focused in front of them. The point where the rays meet is called the "real image". When the two prisms are mounted as in Fig. #8, the light rays seem to be focused behind the prisms. This imaginary focal point is called the "virtual image" and it is seen by looking into the prisms.

FIG. # 7



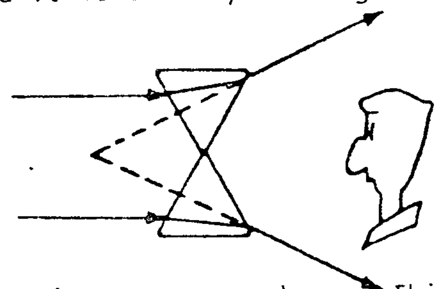


FIG. # 8

The prisms in Fig. #7 can be polished into a convex lens. This type of lens is found inside a camera and it is used to take photographs.

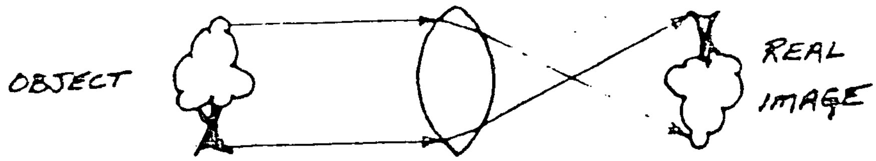


FIG. # 9

The prisms in Fig. #8 can also be polished to make a concave lens. When you look through this lens, objects appear to be smaller than their actual size. This lens is used as a security window on apartment doors because of its wide angle of view.

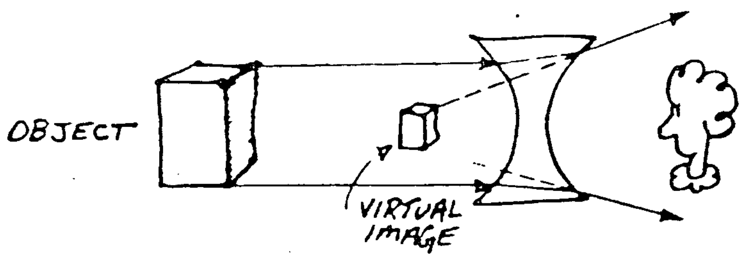
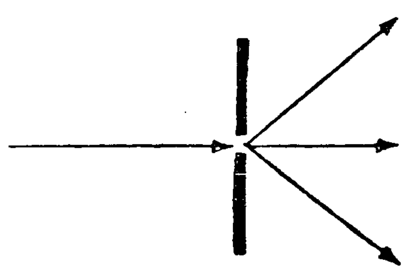


FIG. # 10

DIFFRACTION

As a ray of monochromatic light passes through a small hole, some of the light goes through it as if unbent, while some of the light seems to be bent to either side.

FIG. # 11



If a bundle of rays (a beam) is allowed to pass through a group of holes or slits (called a "diffraction grating") much the same happens.

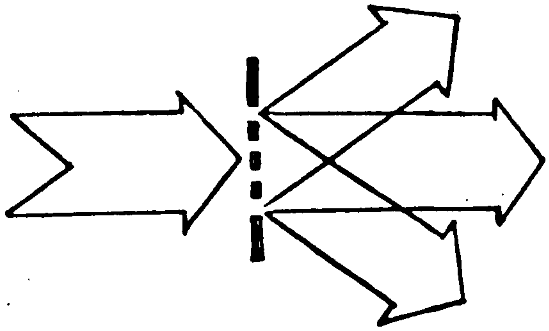


FIG. # 12

The above diffraction grating can be changed in order to focus the light passing through it.

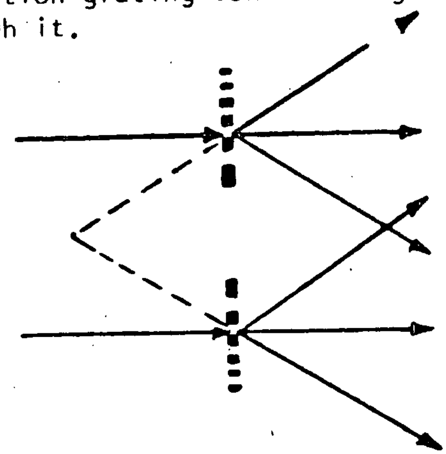


FIG. # 13

As before, some of the light passes through undeflected while some of the light is focused in front of the grating and some of the light appears to be focused behind the grating. If we take the above grating and look at it from the front instead of from the side, it appears as follows:

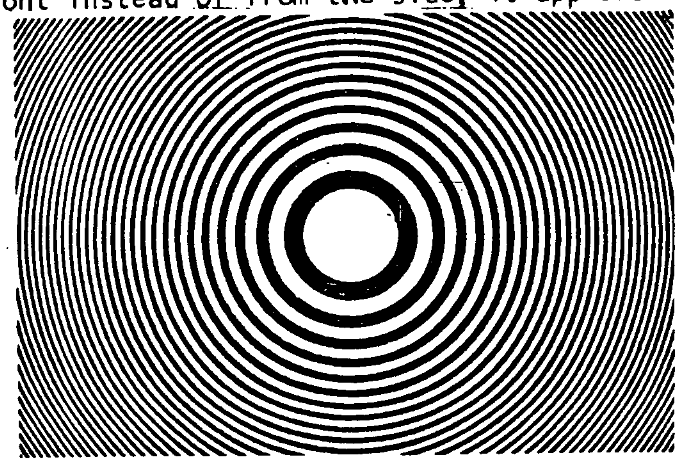


FIG. # 14

This type of grating is called a "zone plate". A zone plate is also a simple hologram. As can be seen by comparing refraction with diffraction, a zone plate behaves somewhat like a combination of a concave and a convex lens.

If I want to make a convex lens so that I can take a photograph, I would have to grind a piece of glass into the shape of a lens. If I want to make a zone plate, or a hologram, I can use a laser.

WHAT IS A LASER?

Both a light bulb and a laser are sources of light. A laser, however, differs from a regular light bulb in two ways. First, most light bulbs emit white light, in other words, light comprised of a variety of wavelengths or colours. A laser, on the other hand, is capable of emitting a very specific wavelength. Secondly, a light bulb is like a bomb with light exploding randomly from the surface of the filament inside its glass casing.

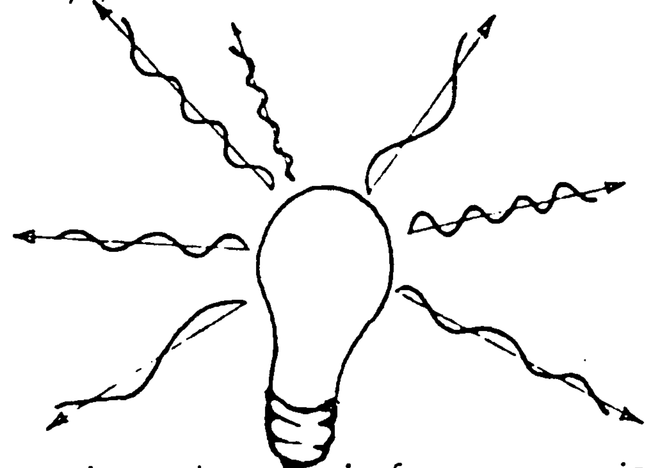


FIG. # 15

The light coming from a laser, however, is far more organized since all of the emitted light rays are synchronized (in-phase) with each other. This means that light is emitted by the laser, first as a series of crests, then as a series of troughs and so on.

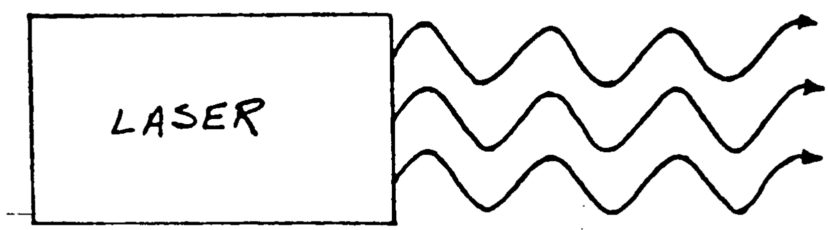


FIG. # 16

Since the light coming from a laser is both monochromatic and in-phase, it is said to be temporally and spatially coherent. It is because of the laser beam's coherence, a property not easily attainable from other light sources, that making a hologram of a three dimensional scene is possible.

HOW TO USE A LASER TO MAKE A HOLOGRAM

A wavelength of light can be symbolized with dark and bright bars. Bright bars indicate crests and dark bars indicate troughs.

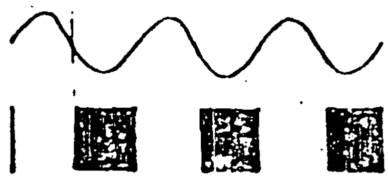


FIG. # 17

Thus the light coming out of a laser can be represented as:

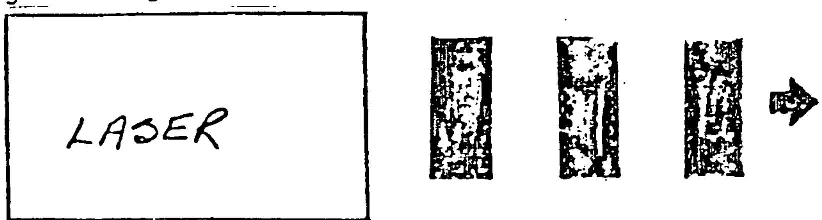


FIG. # 18

A laser's beam can be divided into two parts by a beam splitter (a special mirror) which allows some of the light to pass through it and some of the light to be reflected. If these two beams of light are allowed to cross paths (with the aid of mirrors) a moiré pattern results. An optical moiré pattern is produced when two coherent beams of light interfere with each other.

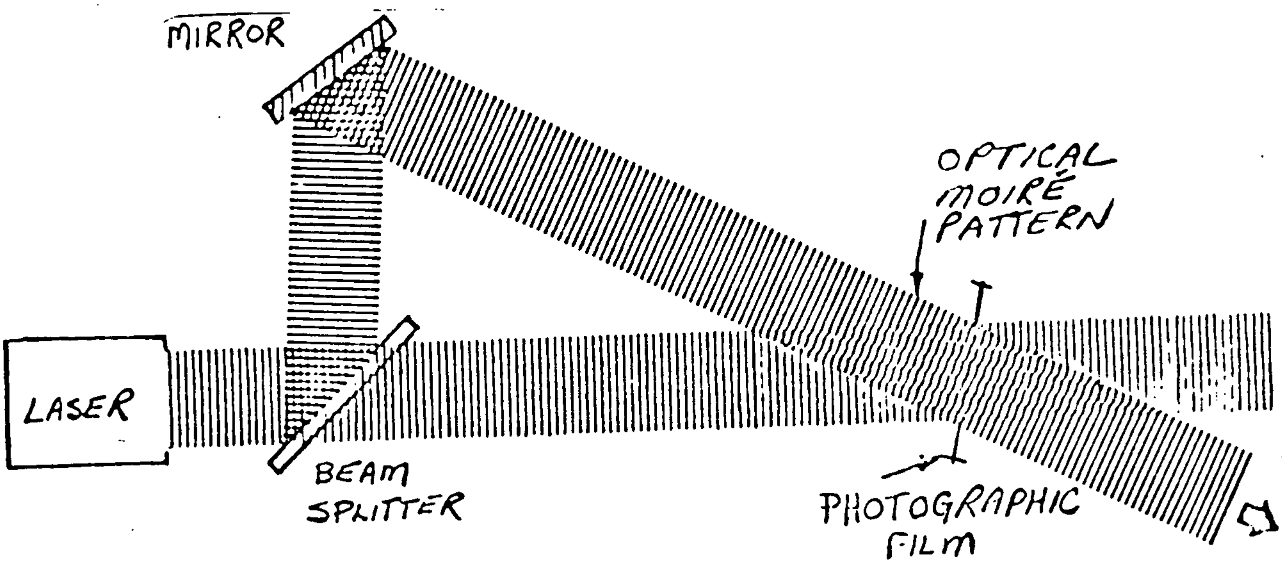
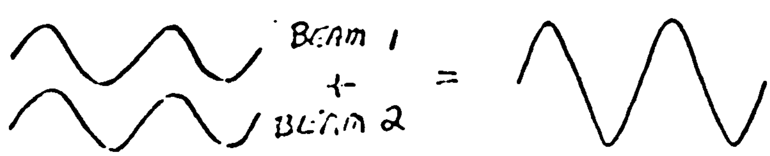


FIG. # 19

When two light waves meet each other in-phase (ie., the crests and troughs of one light beam sit exactly on top of the crests and troughs of another light beam) the result is one light beam whose brightness is the sum of the brightnesses of the two individual beams. This is called "constructive interference".

FIG. # 20



When two light beams and their waves are out of phase (ie., the crests of the one beam coincide with the troughs of the other beam), "destructive interference" occurs and the resulting beam is less bright than either of the two original beams.

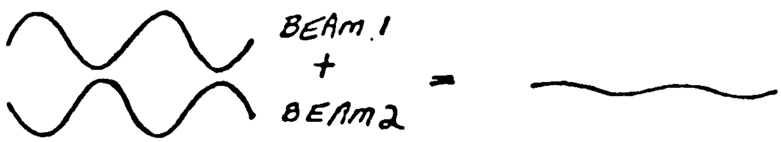


FIG. # 21

Constructive and destructive interference are symbolized by the dark and bright bands which form the optical moiré pattern. The thick dark bands represent destructive interference whereas the lighter spaces between them represent constructive interference (see Fig. #19).

Since light waves are very small (approximately 5x10-7m.) the interference pattern is also very small. However, if photographic film is placed in the path of the intersecting light beams, it will be able to record the moiré pattern which could later be viewed under a microscope. Points of constructive interference will expose the film whereas points of destructive interference will leave the film almost completely unexposed. So if an interference pattern of light exposes a photographic film, which is developed like a black and white negative, the result will be a "picture" which will look very similar to a diffraction grating. If a beam of monochromatic light is passed through this photograph, some of the light beam will pass through as if undeflected and some of the light will appear to be bent to either side (see Fig. #12). Thus by using a laser, some mirrors and photographic film it is possible to make a simple diffraction grating. By introducing a lens into this set-up it is possible to make a zone plate (or hologram).

If a collimated or parallel beam of laser light passes through a convex lens, it will be focused to a point and then it will be spread out to form a "spherical wavefront".

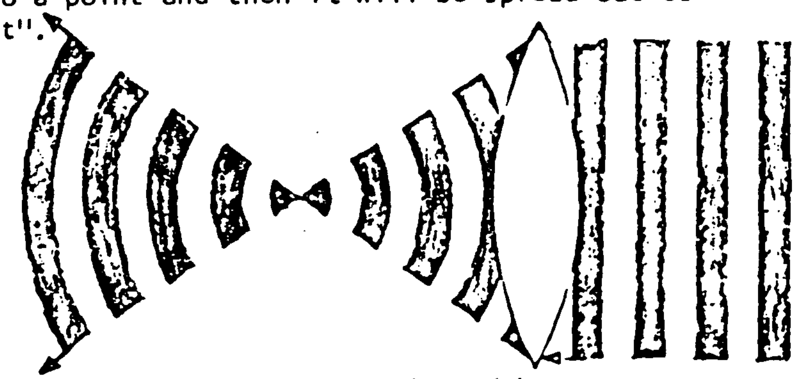


FIG. # 22

To make the simple diffraction grating, two collimated beams were allowed to interfere. If one of the collimated wavefronts is passed through a lens, turned into a spherical wavefront and allowed to interfere with the other beam, a slightly different moiré or interference pattern is formed.

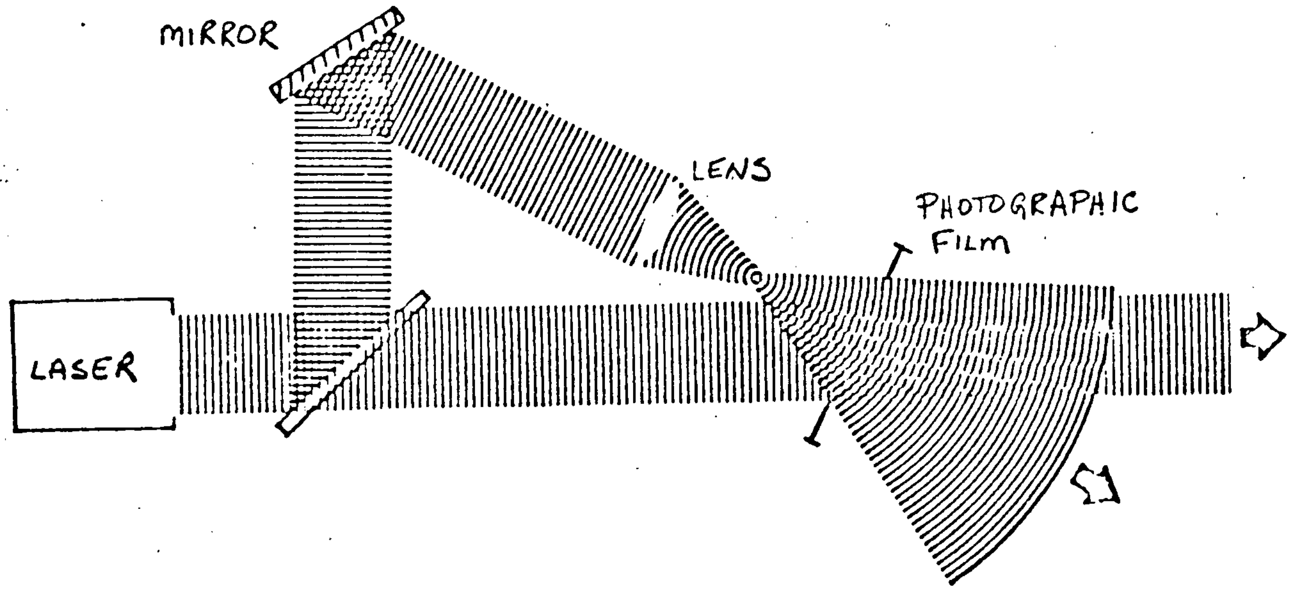


Fig. #23

The above interference pattern is only part of a larger interference pattern formed when a spherical wavefront meets a collimated wavefront. Fig. #24 shows the above pattern in relation to the larger one. The larger pattern is a cross-section of a zone plate.

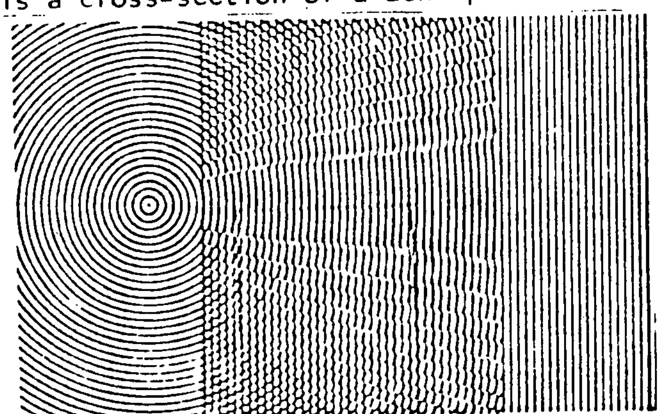


FIG. #24

If this interference pattern is recorded photographically and a beam of monochromatic light is transmitted through the photograph of the zone plate (or only a part of the zone plate), some of the light will seem to pass through undeflected, some of the light will be focused in front of the zone plate and some of the light will appear to be focused behind it (see Fig. #13).

If a complex object is illuminated with a collimated laser beam, the rays of light reflected by that object will be related to the shape and size of that object.

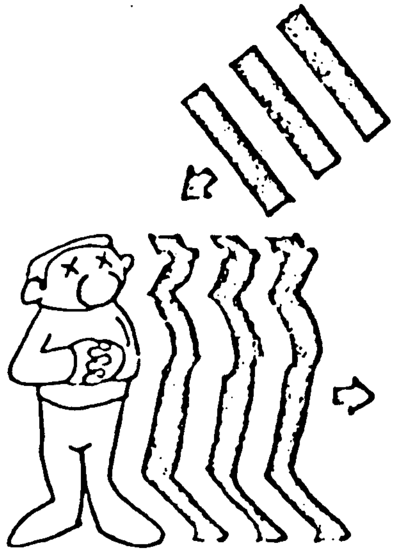


FIG. #25

Fig. #26 is a diagram of a set-up for making a hologram of a complex object or scene.

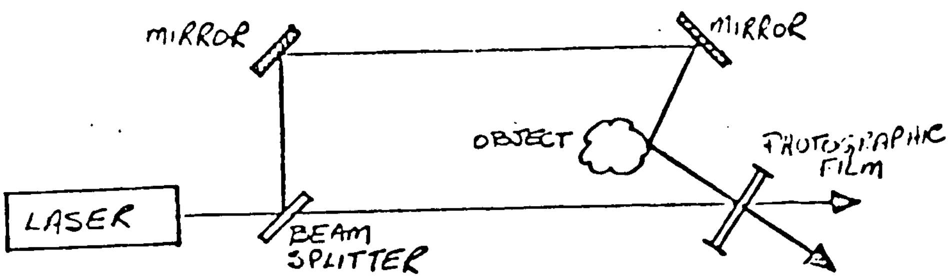


FIG. #26

The complex wavefront coming from the object interfereswith a collimated wavefront. This interference pattern is shown in Fig. #27. As can be seen, the interference pattern is comprised of several zone plates.

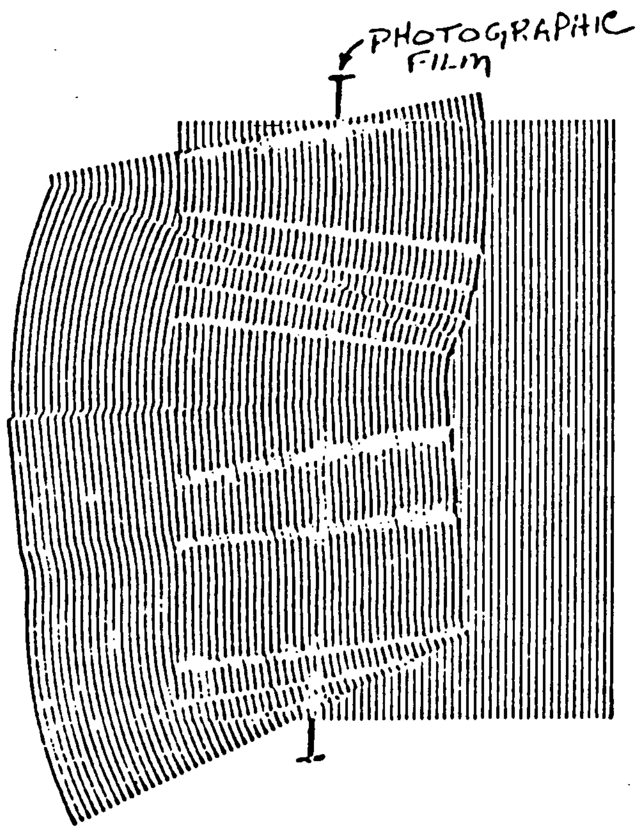


FIG. #27

Once this interference pattern has been recorded photographically and illuminated with a beam of laser light, the light is diffracted by this complex grating in such a way that some of the light passes through it as if nothing has happened to it, some of it is diffracted so that when viewers look into the hologram they will see the virtual image of the object and if they look in front of the holographic plate they will see the real image of the same object focused in space (most display holograms, however, are made so that only one image, either the virtual or real image, can be seen at any one time).

The image of a lens is three dimensional. Taking a photograph of the image of a lens is to record only one aspect of that image. To focus on an image is to move the photographic film through the image. A hologram is actually a complex array of "lenses" (zone plates) which are able to focus light and thereby reconstruct the image of the original scene in all of its three dimensions.

FOR FURTHER READING

Dowbenko, G., "Homegrown Holography", Amphoto, Garden City, N.Y., 1978

Kock, W.E., "Lasers and Holography", Anchor, Garden City, N.W., 1969.

Leith, E.N. & Upatnicka, J., "Photography by Laser", Sci. Amer., Vol. 212, #6, Je. '65.

C.5 Zoetrope

Visitors draw their own cartoons and view them in the spinning zoetrope.

The slits in a zoetrope act like the shutter in a movie projector, allowing each successive image to be seen for the moment that it is in the correct position, and then blanking the screen while the next image moves into place.

This device, also known as the "wheel of life", was invented almost 150 years ago, long before motion pictures, but it is based on the same idea. The illusion of motion arises from the persistence of vision. When our eyes record an image, we continue to see it for a short time, even if the image disappears right away. If a succession of such images is presented, the brain interprets the situation as one of smooth movement, provided the images come at the rate of 16 per second or so. Modern motion pictures are projected at a rate of 24 frames per second, which eliminates the annoying flicker evident in pioneering movies and in the zoetrope.

Learning Outcome:

The student should understand that the Zoetrope operates similarly to a motion picture projector.

D. ILLUSIONS

"Seeing is believing." This saying reflects our faith in what we see. In fact, our eyes give us an amazingly detailed and accurate representation of the world, but errors can occur.

When we see, the world is projected on our retinas as a two-dimensional image. Our brains reconstruct the three-dimensional world on the basis of depth cues. Normally, these depth cues allow the brain to judge distance accurately, but psychologists and artists can juggle these cues, making patterns and objects that trick the brain or overwork the intricate system. Psychologists use visual illusions to study how vision works. Artists use them to create dramatic effects.

General Goal:

The student should understand that seeing is conditioned by what we know. The perception of what we see is affected by both natural and (human) made illusion.

The student should understand that artists use visual illusions to create dramatic effects and that scientists recognize that visual illusions can lead our eyes away from an accurate observation of the world.

D.1. Railway Track Illusion

One explanation of this illusion is that the brain tries to interpret the lines as a three-dimensional scene, so most people see one box as larger than the other.

D.2 Background/Foreground Reversal

In this drawing, it is not clear whether the background is glack or white, because the picture makes sense both ways. The brain thoroughly wipes out the wine glass when someone sees two faces, and vice versa.

D.3 Arrowhead Illusion

A cue of linear perspective provided by the arrowheads (see fig.) makes the vertical line on the right appear longer than the line on the left, even though they are exactly the same length.

D.4 Tilted Lines

In illusions of this kind, straight lines can be "bent" by a set of intersecting lines. In the three examples the horizontal lines are really straight, the circle is really round and the square is a true spuare.

D.5 Twisted Cord

Marks that slant in toward the centre make circles appear to slant in to the centre and look like a spiral. In another illusion the slanting marks make letters look crooked: but they aren't.

D.6 Ames Chair

A collection of sticks becomes a chair. When we look at an object, it casts a flat image inside our eye. The brain has to figure out the true shape, using whatever clues are available. If it gets a misleading but very strong clue (I am a chair!), it can make a mistake.

D.7 Impossible Triangle Realized

The makers of this exhibit had to cheat a little. One of the corners of the triangle isn't really a corner. The triangle is broken open, but without strong depth cues, the brain closes it up. Another part of the brain, the thinking part, realizes something is wrong, but can't undo the illusion.

D.8 Spiral Spin

When an individual looks at the spinning spiral for a long time, the cells in his visual system that detect this kind of motion become overworked. When he looks at the stationary spiral, there is a rebound effect and it seems to spin the opposite way. The rebound will affect other patterns too.

D.9 Three-Dimensional Reversing Cube

This works when the viewer shuts one eye and stares at the cube. Our two eyes see the world from slightly different viewpoints. This allows the brain to sort out distance relationships to create a vivid sense of depth. When one eye is closed, it is easier to confuse the brain about depth.

A GLOSSARY OF COLOUR TERMINOLOGY AND DEFINITIONS

LIGHT

Visible light comprises wavelengths of radiation within the electro-magnetic spectrum. The visual colour spectrum seen when "white" light is split by a prism shows it is composed of wavelengths from RED/ORANGE/YELLOW/GREEN/BLUE/VIOLET.

ADDITIVE

Proceeding by addition: of LIGHT, the process by which colour lights combine to produce white light due to absorption of 2/3rds of the visible spectrum.

ADDITIVE PRIMARIES

Of light: RED LIGHT/BLUE LIGHT/GREEN LIGHT, when combined equal WHITE.

ADDITIVE SECONDARIES

Of light: RED + GREEN = YELLOW
GREEN + BLUE = CYAN
RED + BLUE = MAGENTA

SUBTRACTIVE

Process of taking away: of PIGMENT COLOUR - where combination of colour produces black by absorption of 1/3rd of visible spectrum.

SUBTRACTIVE PRIMARIES

Of pigments: RED/YELLOW/BLUE.

SUBTRACTIVE SECONDARIES

Of pigment: ORANGE/GREEN/VIOLET, theoretically produced from above.

SUBTRACTIVE TERTIARIES

Of pigment: RED ORANGE/YELLOW ORANGE etc. located between primaries and secondaries.

TRI-CROMATIC PRIMARIES

Of pigment dyes: YELLOW/MAGENTA/CYAN employed as transparent inks in printing when combined with the addition of BLACK produce appearance of full colour range.

PIGMENT (GENERAL)

Material organic or inorganic present in all objects, according to composition it will absorb or reflect various parts of light spectrum causing the eye to see it as a colour.

PIGMENT (PAINT)

Selected materials which when ground and mixed with a MEDIUM such as oil/synthetics can be used as paint. Each pigment is known as a specific name which stands within each colour family or hue.

HUE

Distinction between families of colour in pure state; e.g., HUE of RED, HUE of YELLOW, HUE of BLUE. Each hue includes all types of its colour family whether WARM or COOL applies also to secondary/tertiary hence: CONTRAST OF HUE; examples from opposing hues placed together.

WARM

Discriminative interpretation of colour stimuli: in general terms;
RED/ORANGE/YELLOW are associative of WARM
BLUE/GREEN/VIOLET are associative of COOL

COOL

In particular terms as all hues comprise differing degrees of colour, it follows that; e.g., reds may be warm and cool; i.e., a WARM RED will tend towards ORANGE, whilst a COOL RED will tend towards VIOLET etc. Hence, contrast of W/C: within one hue or between hues.

SATURATION

Degree of purity of given colour: Maximum Saturation means colour is in its purest, most intense form, undiluted by any other colour. Hence CONTRAST OF SATURATION: between hues in this state.

DESATURATION

Colour in an impure state, by the addition of other colours. Degrees of desaturation can be established within one hue.

LIGHT DARK

i) Characteristic of hues of colour when compared in their most saturated form: Yellow is inherently LIGHT, Violet is inherently DARK.

ii) Characteristic of PIGMENT sources: in natural state certain pigments appear DARK and their colour characteristics are hidden. Light/Dark contrast can be a confusing element in establishing the other contrast mentioned.

TONE/TONAL

i) Description of degree of Light/Dark tendency of colour.

ii) Description of degree of mono-characteristic range especially, black/white grey.

TINT

Addition of white to a colour.

SHADE

Addition of black to a colour.

COMPLEMENTARY

Relationship between pairs of colours which are totally opposite in terms of hue and degree of warm and cool, so that they mutually enhance each other. Found diametrically opposite on COLOUR CIRCLE.

A complementary pair when mixed tends towards a neutral grey.

HARMONIC

Range of intermediate values produced when any two colours are progressively mixed with each other; e.g., red plus 1 part green/2 parts/ etc. until equal quantities are mixed, then returning to green. Sometimes referred to as BROKEN colour.

DISCORD

Relationship between pairs of colours where the NATURAL ORDER has been slightly inverted: e.g., yellow which is naturally light paired with blue which is naturally darker would discord if they are adjusted so that the blue becomes fractionally lighter and the yellow fractionally darker.

ADJACENT DISCORD
Above relationship established between adjacent colours; i.e., green-blue etc. Also referred to as CLASSICAL DISCORD.

COMPLEMENTARY DISCORD
Discord relationship established between pairs of colours lying diametrically opposite on the COLOUR CIRCLE.

ALTERNATING DISCORD
Discord relationship established between alternate colours; blue-yellow etc.

SIMULTANEOUS CONTRAST
Of perception: the ability of the eye to generate the complementary colour of any given colour stimuli, thus an area of colour will appear to have a complementary edge. If a series of grey areas are placed within areas of saturated colour, the eye will invest the grey with a tendency towards the appropriate complementary.

AFTERIMAGE
Physiological reaction within the eye after receptors of its retina have been exposed to a range of intensity of light or colour, the receptors so exposed become fatigued and their photo pigment is temporarily bleached producing a complementary image.

Afterimage can also be produced from direction and movement.

INTERACTION
Elements or forces which act reciprocally, act on each other,descriptive of certain colour situations.

REACTION
Respond to stimuli; undergo change due to some influence.

CONTRACT GENERAL
Set up relationship between elements: opposition which allows comparative effects to be judged.

INTENSITY
Measure of degree of quality, (sometimes used in conjunction with SATURATION).

GRADUATION
Measure of quantitites: scale or progression demonstrating this.

NATURAL ORDER
Relative positions of subtractive colours, in saturated state to inherent light/dark characteristics, also logical organization as in COLOUR CIRCLE.

COLOUR CIRCLE
Organization of subtractive colours in continuous ring to chart relationships between them.

COLOUR SPHERE
Organization of subtractive colours in the equator of a sphere, with grey in the core, and white and black at the poles. Allowing the charting of Harmonics/Tints/Shades etc.

CHROMATIC

Of the full saturated colour spectrum, derived from Primary/Secondary/ Tertiary ranges.

ACHROMATIC

Free from colour: transmitting light without decomposing it.

MONOCHROMATIC

Of one wavelength (colour) only, range limited to one hue.

QUALITATIVE

Concerned with, depending on quality, hence discrimination of degrees of characteristics of colour.

QUANTITATIVE

Measured or measurable by concerned with quantity, amount, etc., hence: comparison of scale and area of colour, sometime linked with CONTRAST OF EXTENSION.

CONTEXT CONTEXTURAL

Observation of a part seen relative to associated and/or related elements, relationship in which one thing is affected by the other.

JUXTAPOSITION

To place things side by side, may involve placing one element in differing contexts to observe its relative appearance.

PHYSIOLOGICAL

Science of the phenomena and functioning apparatus of living organisms, hence Physiological aspect of colour deals with the human sensory apparatus and how it is affected and interprets colour.

PSYCHOLOGICAL

Science of nature, functions and phenomena of the human mind. Psychological aspect of colour deals with human interpretive and associative responses.

PHYSICAL

Of matter: material properties or qualities of elements constituting matter. Physical properties of colour/pigment involve recognition of; e.g., transparency, translucency, opacity, etc., etc., which may amplify or detract from the required sensation.

BRIEF NOTES CONCERNING CHEMISTS/PHYSICISTS DEALING WITH COLOUR EXPERIMENTS

SNELL	1621	One of the first mathematicians to investigate laws of refraction.
DESCARTES	1596-1650.	1632 published standard work in refraction of light also investigations into size and shape constancy.
HUYGENS	1629-1695	Theories on wavelengths as pulses through the ther.
NEWTON	1642-1727	First to explain composition of "white" light as the spectrum. Published in his "Optik."
ROEMER	1644-1710	Calculated the speed of light.
KEPLER	1571-1630	Early experiments with retina of eye.
MAYER	1723-1762	Devised three colour triangle.
LAMBERT	1728-1777	Invented colour pyramid.
GOETHE	1749-1823	Afterimage experiments, subjective measurement of colour proportions, based on feeling.
YOUNG	1773-1829	Developed the three colour receptor hypothesis of vision.
RUNGE	1777-1810	Invented colour sphere to explain colour pigment orders.
CHEVREUL	1786-1889	Chemist, research into pigment and dye lead to classic work on the Laws of Simultaneous Contrast of colour perception.
SCHOPENHAUER	1788-1860	Further described colour as sensation.
FECHNER	1801-1887	Experiments with stimulus/sensation (Weber/Fechner Law).
HELMHOLTZ	1821-1894	Physiological Optics experiments.
OSTWALD	1853-1932	Originator of the Ostwald Colour System, now looked on with some suspicion (still employed by Winsor and Newton).
MAXWELL		Founder of theory of Electro Magnetic Spectrum. Disc experiments.
HERRING	1834-1918	Four complementary colours with black and white could produce all colour derivatives.
MUNSELL	1856-1918	Organization of system to fix colour, value and chroma in scales (Munsell Reference System).
PAUL KLEE	1879-1940	Theoretical writings of colour and experiments at Bauhaus (Thinking Eye, etc.).
ITTEN	1888-19	Writings on colour systems and experiments. Also taught at Bauhaus.
ALBERS	1889-19	Writings and experiments with colour relationships and structure. (See book Colour and his own paintings.)