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THERMAL ENVIRONMENT AND LEARNING.

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RESEARCH ON THERMAL ENVIRONMENT IN SCHOOLS IS SUMMARIZED AND THE STATUS OF "THERMAL ENVIRONMENT AND LEARNING" RESEARCH COMPLETED AND/OR UNDERWAY IN THE IOWA CENTER FOR RESEARCH IN SCHOOL ADMINISTRATION IS REPORTED. RESULTS ARE--(1) CHILDREN DID LEARN BETTER UNDER MODEL THERMAL CONDITIONS, (2) TEACHERS MUST BECOME MORE AWARE OF THERMAL CONDITIONS, (3) SCHOOL ADMINISTRATORS, BOARDS OF EDUCATORS, AND ARCHITECTS MUST PAY CAREFUL ATTENTION TO THERMAL CONDITIONS IN SCHOOL BUILDINGS DURING PLANNING OF NEW CONSTRUCTION OR REMODELING, (4) LARGE EXPANSES OF GLASS IN CLASSROOMS ARE QUESTIONABLE AND MAKE IT DIFFICULT TO CONTROL THERMAL ENVIRONMENT, AND (5) INITIAL THERMAL ENVIRONMENT STUDIES BY THE IOWA CENTER HAVE BROUGHT QUESTIONS OUT FOR FURTHER RESEARCH. INCLUDED ARE TABLES, PLANS, PHOTOGRAPHS, AND A BIBLIOGRAPHY. (RK)

Thermal environment and learning

by The Iowa Center For Research In School Administration
UNIVERSITY OF IOWA, Iowa City, Iowa

Location of research project,
LENNOX 'Living Laboratory' research school, Des Moines, Iowa

FOREWORD

This report serves a two fold purpose. First, it summarizes research on thermal environment in schools. Secondly, it reports the status of Thermal Environment and Learning research completed and/or underway in the *Iowa Center For Research In School Administration.*

Researchers wishing a more complete presentation of the first pilot study can obtain a digest of a thesis entitled "The Effect of Thermal Environment on Learning" by Charles Peccolo. This thesis contains the design and statistical analysis used in the study. The cost is $2.00.

Much further study is planned on the subject. The second study has been completed and will be published in the near future. It analyzes further some of the interesting findings found in the Peccolo study. The second study especially explores the relationship between intelligence of 6th grade students and thermal environment, and examines the fatigue factor in learning and thermal environment. The second study also duplicates part of the first study to ascertain whether the same results tend to appear.

The reader of this brief monograph is cautioned against making any interpretation, at this point, which would infer that the researchers feel they have enough evidence to warrant a mandate that all school buildings should be air conditioned. However, the evidence does certainly bear out that as a minimum, school buildings should be equipped with the best in ventilation equipment. Heating is no problem—ventilation is a major problem. This is borne out by the fact that in the two studies heat was induced into the classrooms only 3% of the time. The balance of the problem was *ventilation, circulation* and *cooling*. Anytime the outdoor temperature reached 50F the classroom temperature rose above the desirable level unless cooling was introduced.

Thermal environment is as important as a good aesthetic environment. There is little question that heating and ventilating equipment should not be compromised in new school buildings.

This study and others to follow are dependent on a team relationship between industry, public schools and universities. The University of Iowa researchers are professors from educational administration and educational psychology. They set the problem to be studied and its design. Lennox Industries Inc. provided the facilities, equipment and an engineer to work with the University staff. The teachers, principals, children and administrative staff of the Saydel public schools provided the all important human subjects. Mr. Horace Oliver, Superintendent of the Saydel Schools and his staff, displayed an outstanding dedication to basic research in education—a dedication which the researchers feel is an earmark of outstanding educators in this country.

W. R. Lane—Director
Iowa Center For Research In School Administration

WHAT IS THE PROBLEM AND WHY STUDY IT?

Common sense tells us that workers' morale and production can be sustained and improved if they work in a comfortable indoor environment throughout the year. Recently industrial research has proved this relationship between environment and efficiency. Experiments have shown that improvement of thermal environment will increase production in all areas of industry, from heavy manual labor to clerical operations.[1]

Classrooms over-heated

Common sense also tells us that school children are apt to be more productive if the classroom they occupy is comfortable. However, classroom visitation shows that teachers and administrators do not attach much importance to thermal environment. There is little thought or concern about proper humidity, proper air movement, removal of odors or over heating.* Studies show that in January and February, classrooms, even in the northern part of the country, are over-heated (sometimes to 90F or higher). When there is some concern for proper temperature, it is normally to keep the adult teacher happy, not the young students.[2] Even teachers, who like some control over classroom environment, are often hampered by locked thermostats, malfunctioning equipment, and the limitations of "open window" ventilation.

Equipment often minimal

When a new school is being designed and it is necessary to cut costs, often among the first things cut from specifications are classroom unit ventilators. In their place goes some type of inexpensive baseboard radiation that can neither bring in outdoor air for ventilation nor circulate the room air. The public's main criterion is "can we keep the school warm in winter?" No matter what outdoor temperatures might be, the public considers *cool air a* luxury in school buildings. This is true even though more and more people consider air conditioning necessary in their offices, stores, factories and homes.

Another example of lack of concern for thermal environment is the extensive use of glass which creates both solar heat gain problems and heat conduction problems.

It appears that research is necessary to show whether thermal conditions in a classroom have a bearing on the learning processes and behavior of children. We have many reports of test panels and questionnaires on pupils' complaints which tell us what people think about thermal comfort. But there is very little experimental data on the effects of classroom thermal environment on measurable school performances.

*Iowa Center field studies and building surveys.

WHAT WE PROPOSE TO STUDY

Early in 1961 researchers of the *Iowa Center for Research in School Administration* decided it was time to go beyond opinion and conjecture about the effect of thermal conditions on learning. A long range research program was proposed seeking answers to these questions:

I. How is a given type of learning affected by differences in the components of thermal environment?
   - A. Temperature
   - B. Humidity
   - C. Air Movement
   - D. Combinations of factors A, B, C.

II. How do differences in thermal environment affect different types of learning?
   - A. Academic skills (simple addition, etc.)
   - B. Mechanical skills (coding, number matching, etc.)
   - C. Conceptual learning (social studies, science, etc.)

III. How do differences in thermal environment interact with the mode of presentation and type of material?
   - A. Audio-visual
   - B. Teaching machines, programmed learning, etc.

IV. How do differences in thermal environment affect behavior in the classroom?
   - A. Pupil behavior
     1. Discipline
     2. Restlessness
     3. Sleepiness
     4. Tolerance for frustration
     5. Anxiety
     6. Absences
     7. Fatigue
   - B. Teacher behavior
     1. Tolerance
     2. Anxiety
     3. Absences
     4. Morale

V. Do differences in thermal environment affect pupils of different ages to about the same extent?

VI. Do differences in learning occur when children are placed in well lighted, windowless rooms with ideal thermal conditions?
   - A. Effect on morale
   - B. Other psychological effects

Parts of the above research program have been selected for immediate experimentation and study. One pilot study is completed and a second is under way. These studies involve actual teaching situations, and give researchers an opportunity to examine the problems of conducting thermal experiments with school children.

The completed study[3] in the *Iowa Center* series was to determine whether children in a model (good) thermal environment (temperature 69-74F; relative humidity 40-60%; air movement 20-40 feet per minute) would learn better than children who were placed in a marginal environment characterized by poor ventilation, overheating, and uncontrolled humidity.

RESEARCH AND STUDIES TELL ABOUT THERMAL ENVIRONMENT

Many researchers and authorities on thermal environment[4] were polled on the desirable indoor climate. While no two researchers agree on *exact* combinations of temperature, air movement, and humidity, most recommendations fall within the following limits: (1) Air temperature from 69F to 74F. (2) Relative humidity between 40% and 60%. (3) Air movements from 20 to 40 fpm. These recommendations reflect the modern theory called the *Thermal Concept of Ventilation.*

The first scientific theory advanced to explain the effect of the atmosphere upon human health, comfort and efficiency was called the *Carbon Dioxide Theory*. About the time of the American Revolution physiologists presented the view that the presence of carbon dioxide caused the bad effects so noticeable in a poorly ventilated room.

Soon hygienists demonstrated that the increase of carbon dioxide, even in the worst ventilated room was not enough to bring about the toxic effects which had been observed. Pettenkofer, in 1863, theorized that *Organic Effluvia* (noxious gases) given off by the body and lungs were the harmful elements in stale air. Unfortunately, no one was able to identify these organic substances. Pettenkofer then assumed that his hypothetical gases would be given off from the body in the same proportion as carbon dioxide. Allowing that double the normal content of carbon dioxide would be safe, he arrived at a standard of 2000 cubic feet of fresh air per person per hour or 30 cfm.

Engineers of that time believed that ventilating at a rate above three air changes per hour could not be effected without undesirable drafts. As a result minimum square footage allowances per person (by dividing 2000 by three) were set for schools and other crowded places of assembly by the legislatures of many states.

Dr. Winslow, chairman of the New York Commission on Ventilation, observed that the arithmetic of Pettenkofer was fine but the basic assumption was faulty. "These well meant but misguided standards cost millions of dollars in the aggregate and greatly retarded the development of accurate and efficient methods of air conditioning."[5]

Modern research in Germany, the United States and Great Britain has contributed a body of knowledge referred to as the *Thermal Concept of Ventilation.* It has been established conclusively that chemical modification of the air, resulting from gaseous excreta of human beings, is not harmful to health. Such symptoms as headache, fatigue, dizziness and nausea experienced in crowded and poorly ventilated rooms are now attributed solely to inadequate heat loss from the body. And the feeling of freshness when a closed room is ventilated or when we emerge into outer air is due primarily to effective cooling of the body.[4]

IOWA PILOT STUDY ON LEARNING AND THERMAL ENVIRONMENT

The Iowa Center's first thermal study used two groups of students of equal ability, family background and school experience. In all, forty-four matched pairs of fourth grade students were divided into two equal groups and ranked according to achievement as measured by the Iowa Tests of Basic Skills. These two groups were designated as Control Group (marginal environment) and Experimental Group (model environment).

Because the Basic Skills scores were closely similar, it was possible, by shifting equal-scoring children from one group to the other, to obtain a good balance between the two groups in other factors. Factors controlled in the pairings include, age, health, weight, and father's occupation. To equalize motivational factors among the children, no child was told whether he was in a classroom with a model or marginal environment. The researchers were fortunate in receiving the cooperation of the Saydel School District, Des Moines, Iowa, which provided students and teachers for the experiment.

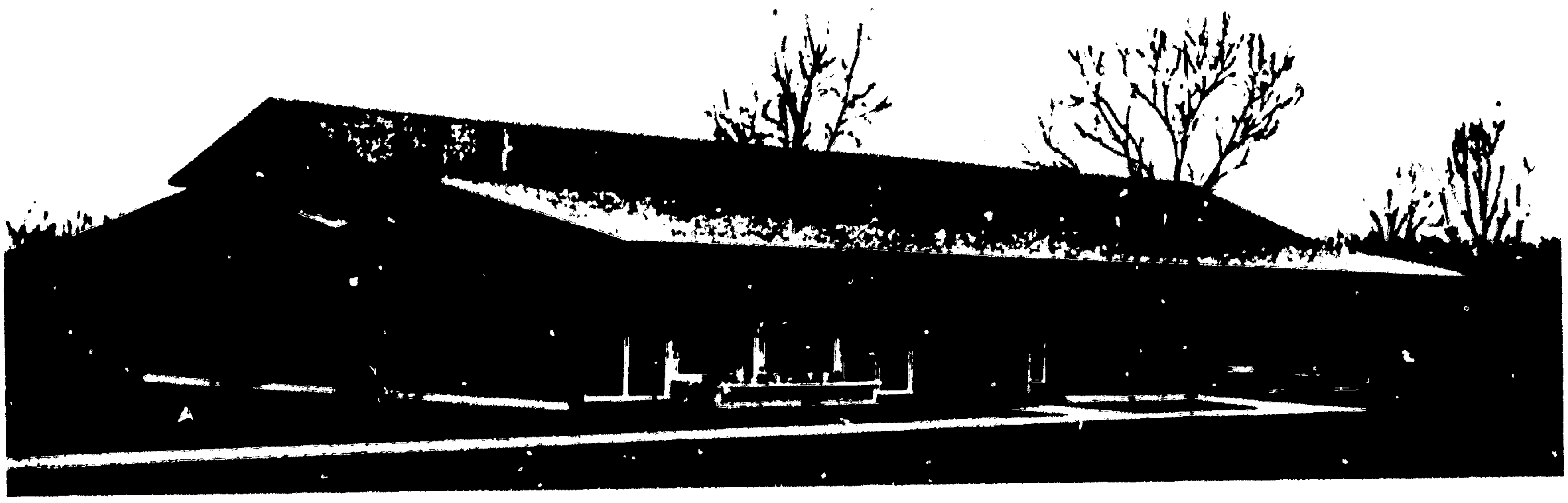
Two kinds of environment

The experiments were conducted at the Lennox Research School building in Des Moines. The school building contains two classrooms which in most respects are typical of classroom construction within the budget capabilities of an average school district. The school, called the "Living Laboratory," was constructed in 1956 for the express purpose of probing new, improved and economical methods of heating, ventilating and air conditioning classrooms. The architectural firm of Perkins and Will, Chicago, Illinois designed the school.

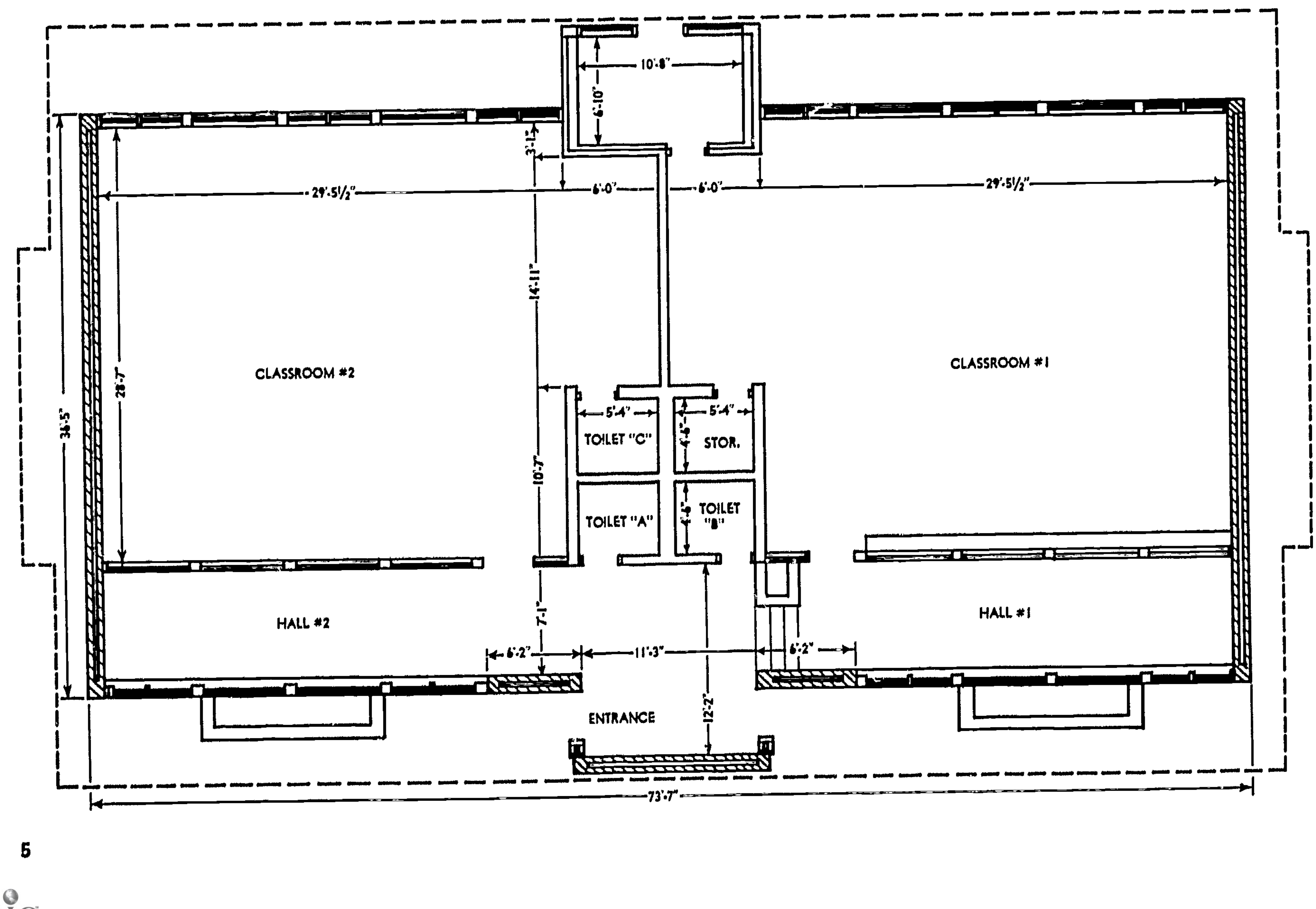
The heating, cooling and ventilating equipment in this school is typical of that currently available. Automatic control of heating, ventilating and air-conditioning is provided. At the rear of the school between the two classrooms is an equipment room. This area houses hot water heating and chilled water cooling equipment, electrical control panels and instruments for testing and measurement. One classroom has an in-the-room gas-fired heater. Complete facilities have been provided for automatically recording temperature at various positions in the rooms, checking velocity and direction of air, and humidity.

The research engineer for Lennox Industries Inc. and his staff are able to produce any thermal conditions desired in the two classrooms. Two kinds of environments were maintained for the experiment: *marginal* and *model*.

The marginal environment classroom limits of temperature, humidity, and air movement were determined by instrument readings in the classrooms of the children's home school. Some winter



"Living Laboratory" research school and floor plans



days the home school temperature went as high as 91F. Heated air, discharged from a duct, provided the air movement in the home school. The velocity of the air across the desks was from five to ten fpm. Humidity ranged from 35 to 75%. The thermal conditions in the marginal environment never reached the extremes of the home school. In the marginal room the teacher could exercise some control over the environment by opening windows and the door and by changing the thermostat. But this was no more control than she would have in her regular classroom.

Maintaining the *model thermal environment* in the second classroom was a complex and challenging task. Allowable temperature limits of 70F to 74F were established. The lower end of this range was considered best for the heating season and the upper range best for the cooling season. The differences noted between the best winter and summer temperatures are based on results of a study conducted by the ASHAE Research Laboratory published since 1950 in the Guide as a Comfort Chart. This study indicates occupants were comfortable at a higher effective temperature in summer than in winter. Air movement was kept between 20 and 40 fpm in the occupied area.

Rapid fluctuations in internal heat gains

The activities in a normal school day and variations in sunshine made control of the model environment difficult. Physiologists tell us that each elementary child gives off heat equal to a 100-watt light bulb. Any experienced teacher can testify to the effects of introducing a class of active youngsters into a comfortable classroom immediately following recess. Temperature of the room jumps 4F to 5F unless compensated by air cooling.

Each time the boys and girls entered the classroom, especially after recess, a considerable heat gain was experienced, even in winter weather. Further the "Living Laboratory," like most contemporary schools, has a considerable amount of glass window area. Solar gain fluctuates throughout the year and had some effect despite the roof overhang of six feet. All fluctuations were controlled by mechanical means in the model classroom.

The research team discovered that if the outdoor temperature rose above 50F, the model environment required ventilation and mechanical cooling, not heating. This was consistent with heat loss vs. heat gain for this particular installation and varied with the amount of solar gain. In the first study, March and April, 1962, the model environment required heating and cooling as noted in the following table.

TABLE 1. HEATING-COOLING CYCLES FOR MODEL ENVIRONMENT

Cycle	% of Occupied Time	% of Outdoor Air Introduced During Cycle
Heating	3	25
Ventilation—outdoor air	32	100
Mechanical cooling	31	*100 or 25
None—Heat Loss vs. Heat Gain in balance	34	25
	100%	

*If outdoor temperature was below 70F, 100% outdoor air was introduced to the room. If outdoor temperature was above 70F, 25% outdoor air was introduced to the room. Refrigeration machinery operated if outdoor air alone could not do the entire cooling job.

In general the relatively small heating time occurred in the morning when outdoor temperature was low. A total change of air in the model room occurred about six times per hour. By volume, each change of air contained about twenty-five per cent outdoor air.

WHAT WE STUDIED

Thus, two groups of matched students and their teachers were engaged in a normal elementary school routine in two different thermal environments. As we shall see, the learning studied was designed to insure that the only difference in the total experience of each group was the difference in thermal environment. Therefore, any significant differences in learning efficiency could be attributed to differences in thermal environment.

In the study the tasks to be measured were administered by one of the researchers. The regular teachers taught the normal school subjects. Learning in the experiment was measured by the number of correct responses to a repeated series of ten paper and pencil tasks. Five tasks involved reasoning activities, four dealt with routine clerical activities and one dealt with new concepts gained via films. Each task was performed at least once a week, several were done daily.

A half hour in the morning and in the afternoon were required to perform the experimental tasks. Otherwise, a normal elementary school routine was followed. Several considerations governed the choice of materials utilized in the measurement of specific learning by the children. It was desirable to tap as wide a range of types of activities as possible. It was necessary, however, to use task materials of the kind and level common in public school curricula, and tests that called for fairly short, quick reaction. Of course, it was important to use for every task such material as would lend itself to objective measurement. See Chart No. 1, page 9.)

The tasks were intended to measure three types of activities which take place in the classroom: (3:8-11)

1. Clerical and Routine Activities—The tasks selected to measure gain in this type of activity were:
   (a) checking names
   (b) checking numbers
   (c) finding and canceling letters
   (d) finding and canceling digits
2. Reasoning Activities—the tasks selected to measure gain in this type of activity were:
   (a) mazes
   (b) design completion
   (a) analogies
   (d) addition
   (e) solving arithmetic problems
3. Activities involving new concepts in a content field (e. g., scientific information presented on film followed by objective tests of film content; care was taken to select a content field with which all children were unfamiliar).
   (a) the Earth: Its atmosphere
   (b) the Earth: Changes in its surface
   (c) the Earth: Resources in its crust
   (d) the Earth: Its oceans

The experiment began March 19, 1962 and was completed May 1, 1962. The tasks were performed simultaneously in the two classrooms. The researcher was with the control group in the morning of the first day and with the experimental group (model environment) in the afternoon of the first day. The order was reversed on the second day. When a film was shown, the researcher presented the film to both groups and the teachers administered the tests.

Each time the youngsters practiced an experimental task (reasoning, clerical or new concepts) the materials were presented in folios prepared in advance. The folios for each practice session were placed, face down, on the students' desks by the researcher. The printed directions accompanying each task were employed as a matter of group instruction. There was no private or individual help. Practice and testing sessions were carefully timed so that children in each environment had equal practice and test periods.

Experiment repeated

One of the classrooms has a ceiling which is twenty-four inches higher than the other. This difference was planned by the architect to be in scale with secondary school furniture originally used in this room for display purposes. To be sure that the difference in room volume had no influence on the results, the experiment was repeated using a second set of fourth graders.

For the duplicate experiment the rooms were switched for the model and marginal environments. Thus, the total experimental group was compared—children exposed to model thermal conditions, half of them in the high ceiling room (first experiment) and half of them in the low ceiling room (duplicate experiment). The total control group was the children subjected to the marginal environment in the two repetitions of the experiment.

WHAT DID WE FIND?

Time trials or tests were made of clerical tasks, reasoning, and new concepts. The first was in the home school, trials 2, 3, and 4 at the "Living Laboratory," and the fifth back at the home school.

Model environment students did better

Considering repetitions of the experiment, every child showed large improvement in three types of activities. But in every reasoning activity the boys and girls in the model environment improved more than the control group in the marginal environment. When analysis of variance procedures was used, the superiority of the reasoning task scores made in the model environment was statistically significant. *That is, the average of reasoning task scores obtained by youngsters in a model environment was superior to an extent that could not be attributed to chance.*

Performance of clerical and routine activities was measured by the tasks presented in Table 3. For all the clerical and routine tasks the results favored the experimental group in the model environment. The higher gains made by pupils in the model environment were statistically significant for the first two, checking names and checking numbers. These clerical activities called for quick recognition and response. The clerical activities tasks involving the canceling of letters and numbers were more routine and monotonous in nature; in this instance the effect of the difference in thermal characteristics was not nearly as great.

The researchers attempted to measure the learning of new concepts (presented by sound films) in the two environments. The Coronet Film series, "The Earth" was used to introduce scientific concepts. Each view of the series was followed by an objective test. Pupils who viewed the films and were tested in the model environment out-performed the control group when both the first and second experiments were considered (Table 4). The difference between the mean scores was not satistically significant.

REASONING TASKS

TABLE 2. AVERAGE SCORES MADE BY CONTROL AND EXPERIMENTAL GROUPS (3:16)

(Task scores are not related)

Task	Group*	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Improvement
Mazes	Control	3.61	4.23	4.75	5.66	5.25	1.64
	Exper.	3.84	4.20	5.07	6.23	5.70	1.86
Design Completion	Control	30.59	38.55	66.73	75.70	72.52	41.93
	Exper.	26.49	53.16	69.25	80.59	79.02	52.53
Analogies	Control	10.05	14.18	17.70	17.50	16.48	6.43
	Exper.	11.34	16.09	18.95	19.55	19.32	7.98
Addition	Control	23.66	27.09	28.45	31.75	31.59	7.93
	Exper.	21.48	27.45	32.11	36.02	35.30	13.82
Solving Problems	Control	10.52	11.77	14.02	14.93	13.41	2.89
	Exper.	11.05	12.89	15.82	17.98	17.84	6.79

*Control—Marginal Environment; Exper.—Model Environment

CLERICAL ROUTINE TASKS

TABLE 3. AVERAGE SCORES MADE BY CONTROL AND EXPERIMENTAL GROUPS (3:16)

(Task scores are not related)

Task	Group*	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Improvement
Checking Names	Control	2.64	2.86	4.23	4.20	3.89	1.25
	Exper.	2.57	3.89	4.48	5.16	5.14	2.57
Checking Numbers	Control	3.82	4.45	5.25	5.89	5.93	2.11
	Exper.	3.64	5.09	6.23	7.20	6.84	3.20
Canceling Letters	Control	25.32	32.48	32.18	39.84	38.82	13.50
	Exper.	23.64	30.59	33.73	42.25	41.61	17.97
Canceling Numbers	Control	45.73	46.89	52.93	55.07	53.23	7.50
	Exper.	40.61	48.36	54.77	57.43	56.34	15.73

*Control—Marginal Environment; Exper.—Model Environment

NEW CONCEPT TASKS

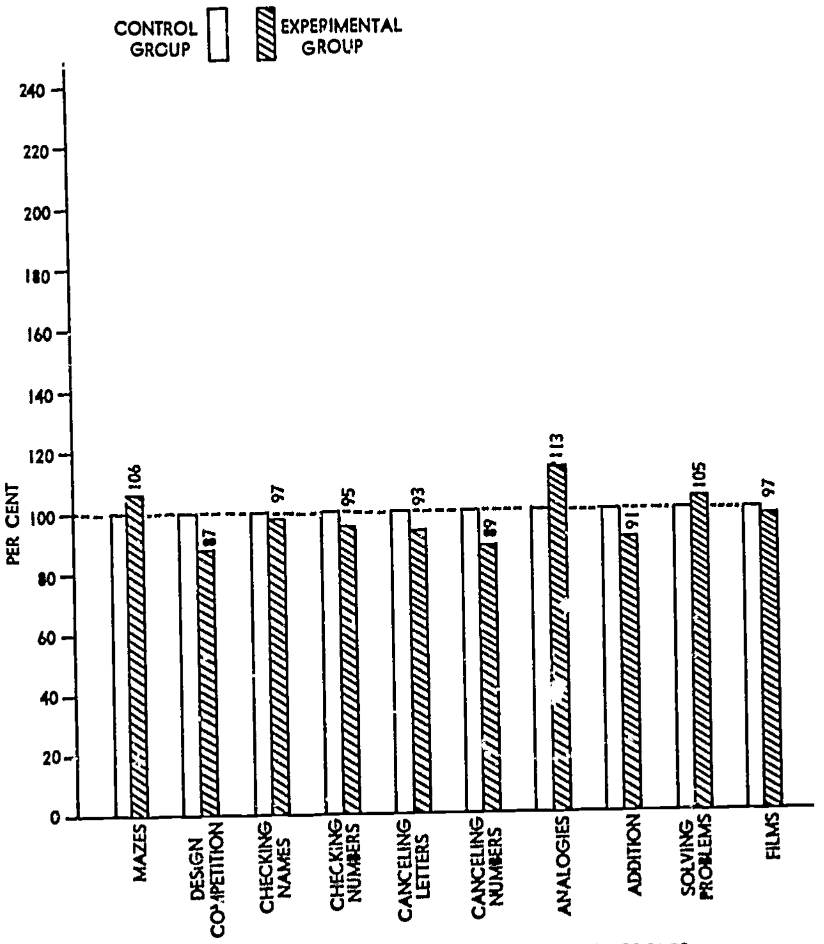
TABLE 4. AVERAGE SCORES MADE BY CONTROL AND EXPERIMENTAL GROUPS (3:16)

(Task scores are not related)

Task	Group*	First Trial	Last Trial	Improvement
Films	Control	8.00	11.09	3.09
	Exper.	7.73	11.80	4.07

*Control—Marginal Environment; Exper.—Model Environment

CHART NO. 1

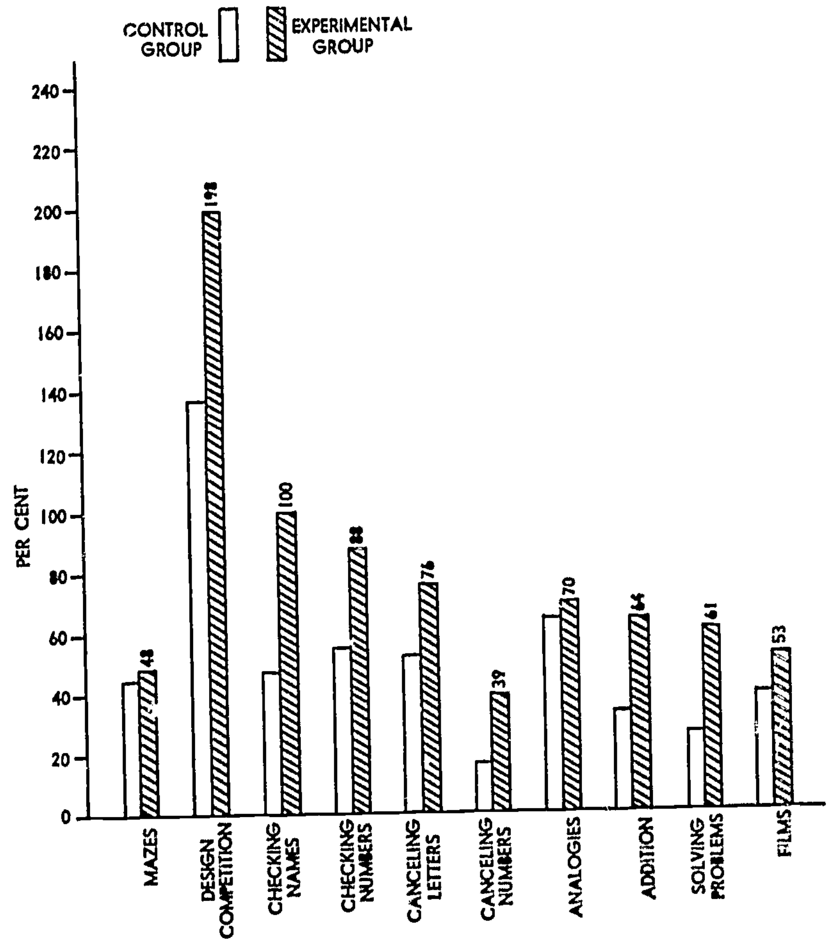


RELATIVE STANDING OF CONTROL AND EXPERIMENTAL GROUPS BEGINNING OF EXPERIMENT

CONTROL GROUP SCORE IS CONSIDERED AS 100%

At the beginning of the test both groups performed about the same.

CHART NO. 2



RELATIVE GAINS IN TERMS OF PERCENT OF FIRST TRIAL SCORE

At the conclusion of the test the students in the experimental environment did much better than the control group.

High ability students did better in model environment

Quite by chance the researchers discovered that the learning efficiency of high ability students was more positively affected by a model environment than that of low ability students. As mentioned earlier, it was considered necessary to duplicate the experiment with a second set of fourth grade children. It happened that the achievement level of this second set of fourth graders was judged to be higher than the average of the first groups of subjects as measured by the Iowa Test of Basic Skills. When the results were analyzed it was apparent that a model environment had less influence on learning of students of lower past achievement. When the students were classified as high level or low level, the average scores of *high* level students in the model environment were significantly higher than the average scores made by *high* level students in the marginal environment. *Students designated as high achievers performed better under model thermal conditions in nine of the ten tasks.*

Placing *low* level students in a model thermal environment had quite different results. *Low* level students in a model environment surpassed the performance of *low* level students in a marginal environment in eight of the tasks. The *low* level students in a marginal environment excelled in working mazes (a reasoning task) and learning of new concepts. (This varied effect on ability levels of a model environment led to another study in which ability is controlled.)

Student opinion sought

The students' reactions to their environment were also of interest. The boys and girls were asked to complete comfort data blanks each day. They were asked to check one of the following responses: "The room is too cold for me; just right for me; or too hot for me" at intervals spaced throughout the day. Students used in the first experiment (those of lower past achievement) had markedly fewer complaints than the second group, regardless of their thermal environment. The boys and girls of the duplicate experiment (those of higher achievement) appeared more sensitive to thermal conditions.

The typical pattern of responses in the marginal environment indicated most of the students were comfortable at the beginning of the day, and then an increasing number checked "too hot for me" towards late afternoon. In the model environment a more balanced pattern was evident. Typically three or four were too cold, a majority said "just right" and three or four replied "too hot."

WHAT DOES THIS MEAN?

Preliminary research by the *Iowa Center* reveals that there is a significant positive relationship between the thermal environment in which children work and study and their efficiency in learning. Children did learn better under model thermal conditions. The knowledge of this relationship affords us increased control over mental functions in the classroom. It adds to our understanding, *gives us power to increase efficiency in learning,* and places on us the responsibility to provide the favorable environment for learning.

School administrators, boards of education, and architects who are responsible for designing and constructing school buildings must pay careful attention to thermal conditions in school buildings at the time of planning new construction or extensive remodeling. Economies gained at the expense of adequate heating and ventilating systems may well have the ultimate effect of inhibiting learning! The large amount of glass in classroom buildings is questionable. Large expanses of glass make it extremely difficult to control thermal environment.

Teachers must become more aware of thermal conditions. All too often the mode of dress for teachers is greatly different from that of students; and considering physiological differences due to age, it is not surprising that a given set of room conditions are not optimum for both teacher and pupils.

The initial thermal environment studies by the *Iowa Center* have brought up questions for further research. The experience gained in preliminary investigations will enable the researchers to continue the studies with more refined equation of teaching, environment, and students.

CURRENT RESEARCH

At present the *Iowa Center* is experimenting with learning of sixth grade pupils in model and marginal thermal environments. Students have been placed in matched pairs according to intelligence as measured by the California Test of Mental Maturity. As a result, the interaction of thermal conditions, intelligence, and learning efficiency can be examined in detail. In the current study, programmed learning materials are used further to insure equality of instruction. Scheduling of learning tasks in the daily program will be examined to determine if there is a fatigue factor which can be overcome in a model environment. A report of this research will be forthcoming in a later *Iowa Center* publication.

Already very specific questions have been raised:

1. Will narrower ranges in the control of the elements of the thermal environment mean proportionately greater gains in learning?
2. Is there an inter-relationship between temperature, humidity and air movement? Will learning be affected if one or two of these factors are at an optimum level and the third not at optimum level?
3. Would the superiority of the group in an ideal thermal environment become even greater if the experiment were extended over a greater length of time? Or would it reach a ceiling or plateau of successful utilization? (Study now underway.)
4. What role, if any, does the thermal environment play in partially neutral functions such as hearing and vision, in pure memory, in learning of vocabulary, in reaction time, in uses of automated teaching devices, in fine muscle work and the creative arts? (Study now underway.)
5. Is there any relationship between pupil and teacher morale and thermal environment?
6. Can learning be sustained at a high level in a windowless, well lighted, attractive classroom if thermal environment is ideal?
7. Is there a fatigue factor present which can be overcome in a model environment? Do children tend to tire more by the middle of the afternoon in a poor thermal environment than in a model environment? (Study now underway.)

Further analysis should be given to the phenomena regarding individual intelligence and reaction to thermal environment. (Partly included in a study now underway.) Further studies should be developed using students from various grade levels ranging from kindergarten through college. (Older students—6th grade—are now used in a second study.)

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